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Research on maritime traffic risk prejudgment and accident causation analysis of Laotieshan Channel

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RESEARCH ON MARITIME TRAFFIC RISK PREJUDGMENT AND ACCIDENT CAUSATION ANALYSIS OF LAOTIESHAN CHANNEL

By

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DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation: **Research on Maritime Traffic Risk Prejudgment and Accident Causation Analysis of Laotieshan Channel**

Degree: **MSc**

The purpose of this paper was to research on maritime traffic risk prejudgment and accident causation factors analysis based on the systematical analysis of accidents occurring in Laotieshan Channel. Firstly, according to the introduction of the characteristics of the maritime traffic accident and the status of relative research in this field to identify the significance of this study and the main method would be used in the paper. Laotieshan Channel as the research object in the paper has been comprehensive interpreted from the aspects of natural environment and traffic conditions. In addition, in light of most of accident analysis methods are based on conceptual models that lack systematic analysis and risk prediction functions, which may not meet complex and changeable situations of accidents, therefore, the author would divide the Laotieshan Channel into four major navigable sea areas for maritime risk prejudgment in advance based on traffic conflict technique. And the fault-tree method would be also used in this paper, which is from the consequence of the accident to find out the top event, direct reasons and indirect reasons of the accident. The analysis

process of accident by fault-tree method would be helpful for accident causation factor identification. Last but not least, conclusions and recommendations would be raised for reduction of the occurrence possibility of accidents and improvement of maritime traffic safety in Laotieshan Channel.

KEY WORDS: Risk Prejudgment, Accident Causation, Maritime Accident, Maritime Condition, Laotieshan Channel.

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LIST OF ABBREVIATIONS

IMO	International Maritime Organization
MSC	Maritime Safety Committee
SOLAS	Convention on the Safety of Life at Sea
TCT	Traffic Conflict Technique
SRS(a)	Ship Routing Scheme
SRS(b)	Ship Reporting Scheme
ECDIS	Electronic Chart Display and Information System
EMSA	Electronic Maritime Safety Administration
VTF	Vessel Traffic Flow
VTC	Vessel Traffic Conflict
PSC	Port State Control
FSC	Flag State Control
VTS	Vessel Traffic Service

CHAPTER 1

Introduction

1.1 Background

Along with the development of the shipping industry in China, the number of ships is increasing continuously, and more large and various ships have been developed and gone into operation as well, which increases the risk of the occurrence of maritime traffic accidents undoubtedly. Maritime traffic accident characteristics research and causation analysis has become a hot issue that is concerned by maritime administration authorities and other relative departments seriously.

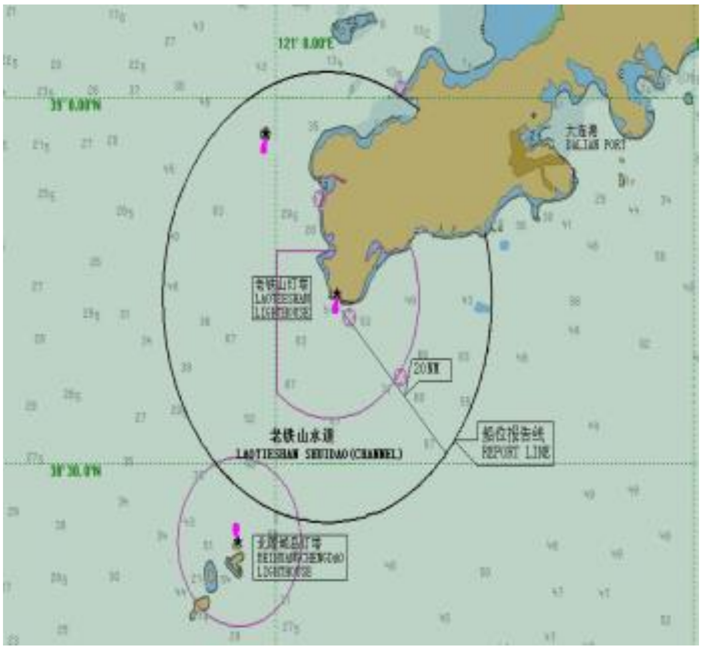


Figure 1.1 The Location of Laotieshan Channel

Source: ECDIS, 2015

Laotieshan Chanel as one of the most important waterway in northern China which is the passage for a large number of vessels entering and leaving Bohai Bay by years. However, due to the changeable natural environment and complex traffic conditions, the maritime traffic accident occurs frequently. Thus, maritime risk prejudgment and accident causation factor identification of the channel has a practical significance of maritime administration and accident prevention for maritime competent authorities.

At present, most of accident analysis approaches are based on conceptual models lacking systematic analysis and risk prediction functions, and they may not cope with complex and changeable situations of maritime traffic accidents (Celik, M., 2013). Therefore, the traffic conflict technique and fault tree method would be used in this paper for maritime risk analysis and accident causation prejudgment.

1.2 Objectives of Research

The research paper is aimed to systematical analysis of the accidents occurring in Laotheshan Channel and work for targeted measures of reduction of possibility of the accident, in addition, to assist maritime administration authorities and port competent departments in and decision-making by maritime risk prejudgment and accident causation factors identification. There are several accident statistics and analysis methods of Laotieshan Channel at present, and most of which are based on conceptual model lacking of quantitative analysis of various risk factors of the accident (Shao, Z. P., 2008). Therefore, traffic conflict technique (TCT) and fault tree analysis method would be used in this paper to prejudge the maritime risk and identify accident causation factors of Laotiehshan Channel. The main research objectives of this research paper are indicated as follows:

a. Reviewing several current accident analysis methods used frequently and interpreting the mechanism and process of accident analysis.

b. Introduction of maritime traffic condition of Laotieshan Channel.

c. Prejudgment of maritime risk factor of Laotieshan Channel by traffic conflict technique.

d. Identification and ranking of accident causation factors of Laotieshan Channel by fault tree analysis method.

1.3 Methodology

The literature review and logical analysis had been used widely in this research paper. There were appropriate IMO documents and circulars, international conventions, articles from contemporary journals, books from libraries of DMU and WMU and information from websites, all of which included in the literature review were used for the aspect of view support. Furthermore, relative statistical figures and secondary resources used for quantitative analysis were provided by Dalian Maritime Safety Administration and port competent departments. Interviews of shipping company and Seamen's Employment Agency were also carried out for relative data collection.

Logical analysis in this research paper was based on corresponding mathematical method and logical analysis approach. Such as the traffic conflict technique was adopted for maritime risk prejudgment and fault tree analysis method was used for identification of accident causation factors.

1.4 Structure of Research Paper

This research paper consists of six chapters. The Chapter One provides the research background, objectives, methodology and structure of the research paper. Chapter Two will give an overview of maritime traffic accident which includes the research status of maritime traffic accident in China and the world, some accident analysis method using, classification and ranking of the accident and the characteristics of the maritime traffic accident. Chapter Three is going to interpret the maritime traffic conditions of Laotieshan Channel from the aspects of natural environment, vessel traffic flow distribution, ship type statistics, ship route analysis, etc. In Chapter Four, vessel traffic conflict theory will be introduced to prejudge the maritime risk in Laotieshan Channel based on the relations between vessel traffic conflict and other factors influencing maritime safety. Chapter Five will analyze the characteristics of the accidents in various ranking and time. In addition, the fault tree analysis method is used for identification of accident causation factors of the accident. Last but not least, conclusions of the research paper and recommendations for maritime administration authority will be given Author.

CHAPTER 2

Status and Method of Accident Analysis Research

2.1 Status of Research on Maritime Traffic Accident

2.1.1 In China

In the case of domestic knowledge, maritime is a short name of maritime accident, maritime loss and maritime casualty, there are no substantive differences between them. (Sun Jun, 2014) Actually, maritime accident refers to the accident of ship, raft and facility occur on the sea; maritime loss highlights the loss of property, and maritime casualty emphasizes the death and injured person in the accident. According to the statistical method of maritime traffic accidents adopted by Ministry of Transport of China, 2014, that has defined and classified the maritime traffic accidents into 10 categorizes (Ministry of Transport of China, 2014):

(a) collision; (b) grounding; (c) on rocks; (d) contacting damage; (e) wave damage; (f) fire and explosion; (g) wind damage; (h) self-sinking; (i) operational pollution; (j) other categorizes of maritime accidents resulting in casualties, direct economic loss or environmental pollution.

At present, the research on accident characteristics and statistical methods has made some progress in China. The experts in this field have researched on accidents in qualitative rather than statistical analysis in quantitative, which has been developed to the stage of preventive measures by accident causation analysis.

2.1.2 In the World

More words are used for defining "maritime accident" internationally than in China, which can be classified into 5 categories: maritime accident, maritime distress (maritime loss), shipping accident, ship accident, and shipwreck accident, etc. There are many English expressions of the concept of the maritime traffic accident in the world. The International Maritime Organization (IMO), in its international conventions, General Assembly Resolutions, Rules, Guidelines and other documents, mainly uses the word “maritime accident” or “maritime incident”.

Maritime Safety Committee(MSC) of IMO has defined 10 categories of maritime accidents as collision, grounding, fire or explosion, ship damage, mechanical failure, equipment damage, capsizing or overturning, natural disasters and other categorizes of maritime accidents in the maritime accident and incident investigation report of Circular 953 (IMO, 2000).

Internationally, in order to promote the cooperation of maritime accident investigation between states and unify the different manners of accident investigation, IMO has adopted and developed some conventions, regulations and General Assembly Resolutions to propose relative requirements and suggestions for maritime investigation, some provisions about the maritime investigation report also included (Schroder, J. U., 2017). However, there is still no explicit terms for the report to the competent authority after the maritime traffic accident occurred, besides, there is only for the obligation that the states should ensure relative documents of investigation result submitted to International Maritime Organization, such as the Article 21 of SOLAS Convention 1974: each state shall provide relevant information about the maritime investigation results to the International Maritime Organization; any report or proposal offered by International Maritime Organization based on which shall not reveal the identity, nationality or any manner will definite or imply the responsibility of ship and personnel (IMO, 1974).

2.2 Status of Research on Accident Causation

2.2.1 In China

At present, research on accident causation in China is mainly based on the theoretical model of maritime traffic accident by Hao Yong, which is the application and development of Heinrich causal chain theory. The model is used to identify accident causations and their relations with the accidents. The theory holds that accident causation is not isolated, damage may occur suddenly, but it is a result of succession of events happening one after another. Since 1980s, the international maritime community believes that the main cause of maritime accidents is human factors, and the main measure to control human factors is to strengthen management on sea (Guan, Z.J.,2011).

2.2.2 In the World

Traffic Conflict Technique (TCT) and Accident-Causing Theory are widely used for accident causation analysis in the world, that is, summary of the mechanism of accident by analyzing the causes from a large number of typical accidents.

Traffic Conflict Technique began to be applied in the United States from the 1950s. The definition of traffic conflict is unified in 1977, the first International Conference on Traffic Conflict held in Oslo, Norway: two or more ships are close to each other to a certain extent in a certain time and space, if they don’t change their states of motion at the time, there will be a risk of collision between them, which is known as traffic conflict (Xiao, Y.T., 2013).

Traffic Conflict Technique can also be expressed as the deck officer is clearly aware of the existence of the accident risk, and takes a positive and effective behaviors to prevent from traffic accidents. Traffic Conflict Theory is a kind of technical method based on quantitative measurement and judgment standard to measure and assess the occurrence process and severity of traffic conflict, and that is always applied in risk assessment and safety improvement.

2.3 Typical Accident Analysis Models

2.3.1 Bowtie Model

The Bowtie Model was first proposed by the University of Queensland in Australia, because that was named by its overall structure which looks like a "bowtie". Based on years of research, the model has been introduced into commercial practice by Shell Oil Company and that has been widely used in risk management research in China and world in recent years (Aqlan, F., 2014). Typical structure of Bowtie Model is shown as Figure 2.1

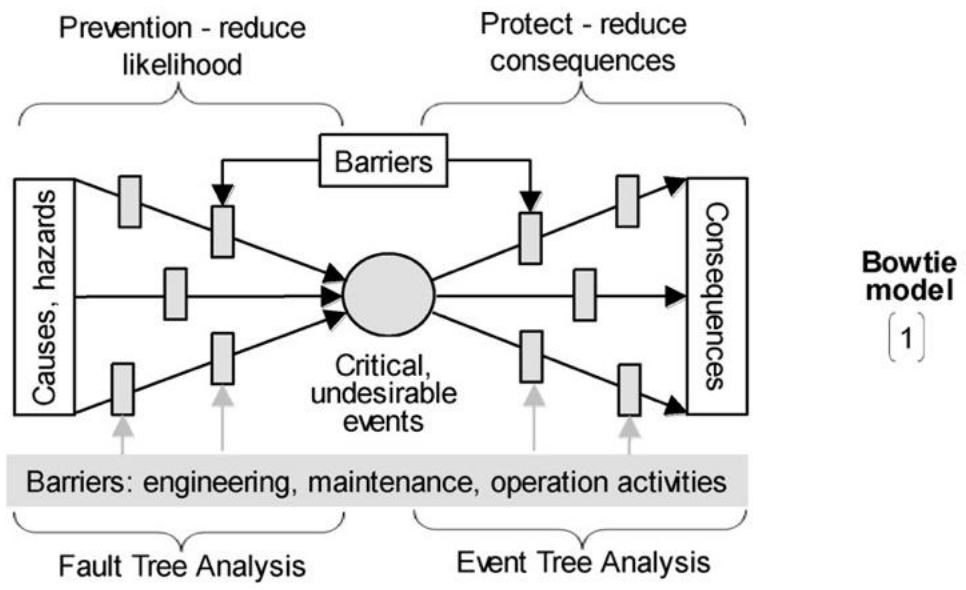


Figure 2.1 Typical Structure of Bowtie Model.

Source: Harrald. Using system simulation to model the impact of human error in a maritime system, 1998.

Bowtie Model could be used for accident causation analysis and incident consequences analysis by the combination of fault tree analysis method with event tree analysis method. The model is mainly constituted by 5 parts which are the hazard source, pre-accident preventive measure, top event, post-accident control measure (emergency treatment measure) and the accident consequences. The top event as the core of the incident is located in the middle of the model; the left side is the accident tree which consists of the hazard source caused by operation process when the accident occurred and the top event of the incident; the right side is the event tree of the incident consequence and the top event. There are pre-accident prevention measures and post-accident control measures among the hazard source, the top event and the accident consequence respectively, all of which constitute the safety barriers of the whole model.

In Figure 2.1, the control measures from left to right should be implemented in accordance with the priority of the source elimination, risk prevention, deterioration prevention and consequence mitigation. The hazard should be eliminated at the source if it could be done; if the hazard that can't be eliminated should be prevented to some extent through safety standards and safety equipment; in addition, if the accidents have occurred or can't be avoided any more, it should be dealt with quickly to prevent the situation from deterioration; finally, when the measures above are not able to implemented that should be handled properly and the remaining work completed as well as possible to mitigate the deleterious consequences (Saud, Y.E., 2014).

2.3.2 Swiss Cheese Model

Swiss Cheese Model was proposed in 1990 by James Reason, a professor of psychiatry at the University of Manchester in England, which is also known as the "cumulative behavior effect". Swiss cheese model believes that the occurrence of accident caused by factors in different 4 levels in an organization (4 slices of cheese), which includes: organization effect, unsafety supervision, sign of unsafe behavior, unsafe operation behavior.

Each piece of cheese represents a defensive system, and the holes in each piece represent gaps or defects in the defensive system, and the positions and sizes of these holes are constantly changing. When the holes in each piece of cheese are lined up in a straight line, an "accident chance trajectory" is formed. And the hazard will pass through the holes in all defensive measures to result in an accident (see Figure 2.2). The holes in the 4 slices of cheese are dynamic at any moment, the coinciding process of size and position of which perfectly is the process of accumulation of fault behaviors and the occurrence of accident. This is called “cumulative behavior effect". Professor James. Reason's "Swiss Cheese Model" emphasizes the systematic view of adverse events which believes that the main cause of the accident is the system defect. In an organization, if a multi-level defense system is built, faults or vulnerabilities will be blocked by the defense system for each other, and the system will not fail because of a single unsafe behavior (Hashemi, R.R., 1995).

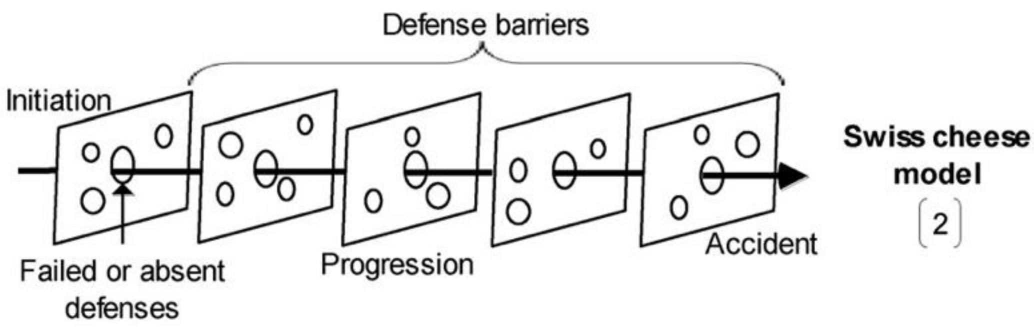


Figure 2.2 Typical Structure of Swiss Cheese Model.

Source: Harrald. Using system simulation to model the impact of human error in a maritime system, 1998.

2.3.3 Framework for Maritime Transportation Model

The framework for maritime transportation model (see Figure 2.3) was presented by Professor Harrald in 1998. The model states that the accident should be generated by a six-stage chain of causes, root or basic cause, immediate cause, triggering incident, accident, consequence and impact. And the reasons of each accident can be categorized into three types, people, machine and environment. In order to be able to predict the accident risk, the possibility of various accidents should be evaluated in the model, but

Professor Harrald also said that this contact of which is difficult to be established, and that requires a lot of assumptions and available data. (Huang, Y.H., 2013)

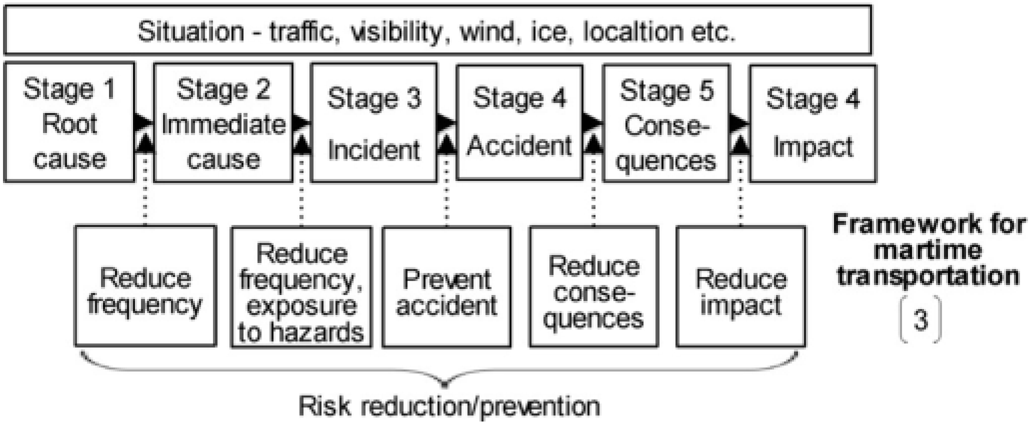


Figure 2.3 Typical Structure of Framework for Maritime Transportation Model.

Source: Harrald. Using system simulation to model the impact of human error in a maritime system, 1998.

2.4 Accident Classification and Ranking

According to the location where the maritime traffic accident occurs, the accidents can be divided into the accident on sea and accident in river; in accordance with different ship types , they can be divided into passenger ship, fishing boat, barge and tugboat accident and so on; in light of the ship status at the time of accident, they can also be divided into the accident in navigation, in berthing and in operation; and the accidents also can be divided into ship accident and floating facility accident, etc. on the basis of different objects in accidents. Thus, there are some different classification methods according to different standards of classification. The scientific and reasonable classification of maritime traffic accidents is the basis for scientific and correct investigation and treatment of maritime traffic accidents.

The new "statistical method of maritime traffic accidents" adopted by the Ministry of Transport of China on September 30, 2014. According to the method, maritime traffic accidents have been divided into ten categorizes by various accident causations (Table 2.1).

Table 2.1 Maritime Traffic Accident Categorized by Various Accident Causations

Accident category	Accident causation
Collision	accidents caused by collision of ships or between ships with mobile platforms or rafts.
Grounding	damage and suspension of ships caused by getting on the shallows
On the rocks	colliding or lying on the rocks
Contacting damage	ships collided the fixed objects such as docks, beacons and drilling platforms, etc. and other obstacles like wrecks, stakes and grilles, etc.
Wave damage	wave caused by the ship impacting on other ships, rafts and facilities.
Fire and explosion	explosion and fire caused by lightning or other reasons that result in ship damage meeting the accident standard
Wind damage	accident caused by strong wind
Self-sinking	sinking, overturning, total loss of ships due to overload, improper loading, improper operation, hull leakage and other reasons or unknown reasons
Operational pollution	ship pollution caused by improper operation
Others	other categorizes of maritime accidents resulting in casualties, direct economic loss or environmental pollution

Source: Ministry of Transport of China, statistical method of maritime traffic accidents, 2014.

In accordance with the casualties and direct economic losses, accidents are ranked into: minor accident, ordinary accident, major accidents, serious accident, and extraordinarily serious accident. See Table 2.2 for details.

a. Extraordinarily serious accident, refers to the accident results in more than 30 people's death (including missing), or more than 100 people seriously injured, or more than 1,000 tons of oil spills which result in water pollution, or more than 100 million RMB of direct economic losses;

b. Serious accident, refers to the accident results in more than 10 and less than 30 people's death (including missing), or more than 50 and less than 100 people seriously injured, or more than 500 tons and less than 1000 tons of oil spills which result in water pollution, or more than 50 million RMB and less than 100 million RMB of direct economic losses;

c. Major accident, refers to the accident results in more than 3 and less than 10 people's death (including missing), or more than 10 and less than 50 people seriously injured, or more than 100 tons and less than 500 tons of oil spills which result in water pollution, or more than 10 million RMB and less than 50 million RMB of direct economic losses;

d. Ordinary accident, refers to the accident results in more than 1 and less than 3 people's death (including missing), or more than 1 and less than 10 people seriously injured, or more than 1 tons and less than 100 tons of oil spills which result in water pollution, or more than 1 million RMB and less than 10 million RMB of direct economic losses;

e. Minor accident, refers to the accident not meeting the criterion of ordinary accident.

Table 2.2 Ranking of Maritime Traffic Accidents.

Grade Criterion	Extraordinarily serious	Serious	Major	Ordinary	Minor
Death or Missing (people)	≫ 30	≫ 10, <30	≫ 3, <10	≫ 1, <3	<1
Injured (people)	≫ 100	≫ 50, <100	≫ 10, <50	≫ 1, <10	<1
Oil spill (ton)	≫ 1000	≫ 500, <1000	≫ 100, <500	≫ 1, <100	<1
Economic losses (million)	≫ 100	≫ 50, <100	≫ 10, <50	≫ 1, <10	<1

Source: Ministry of Transport of China, statistical method of maritime traffic accidents, 2014

2.5 Accident Characteristics

The maritime traffic accident is comprehensive, complex and dynamic that is caused by basic elements of various accidents uncoordinated with each other. Each of accidents is the result of a series of related incidents interacted with each other in accordance with their unique relationship, and its harm is enormous. Therefore, maritime traffic accidents have the characteristics: huge losses, serious harm, regularity, randomness and small probability (Haastrup, P, 1999).

2.5.1 Huge Loss

With the rapid development of China's economy, China's shipping industry has also developed rapidly which has become the major manner of good transportation after China's accession to the WTO especially. However, the increasing number of ships, crowded traffic condition, poor maritime environment, that will increase the risk of maritime accident, and which will also cause huge casualties and economic losses. For example, in March 1989, the oil tanker "Exxon-Valdez" was grounding on the coast of Prince William Bay, about 36,000 tons of crude oil spilled into sea which cost more than $ 8 billion in the form of pollution costs, fines and clean-up expense. The October 28, 2007, a Shanghai cargo ship, carried 4909 tons of steel, sank in the Laotieshan Channel of DaLian waters that resulting in 4 people dead and 12 people missing and the total loss of goods. In terms of the whole country, in 2009, China has lost 336 human lives and nearly 1.5 billion yuan of direct economic losses due to maritime traffic accidents. In 2014, there were 270 maritime traffic accidents, 277 people died, 165

Figure 2.4 Accident Particulars of "Exxon-Valdez"

Source: http://www.response.restoration.noaa.gov/search/Exxon/

ships sank and the direct economic loss was 466 million yuan. Thus, it can be seen, the loss caused by maritime traffic accident is so great.

Figure 2.5 Clean-up Efforts After the Exxon Valdez Oil Spill

Source: http://search.archives.gov/search?query=Exxon+Valdez

2.5.2 Serious Harm

According to relative statistics, 35% of marine environment pollution is caused by ship pollution. Among them, the most important is the oil pollution (Corovic, B., 2013). It is estimated that, there are as many as about 1000000 tons of oil discharged into the ocean due to oil transportation activities each year, which is 10 times as many as that caused by human activities. The ship pollution accidents, especially the harm of marine pollution accident by oil tankers and chemical tankers are very serious. Because once the ship has an accident whose chemicals and other dangerous goods will destroy the marine environment and marine organisms completely and in long-term. In addition, it will result in huge economic losses and negative impact on coastal navigation, even the normal life and health of the residents nearby will be influenced. The November 13, 2002, a Bahamian oil tanker "Prestige" encountered a strong storm off the northwestern coast of Spain, which caused the hull cracked and then large quantities of fuel spilled into the sea. The "Prestige" had lost control and approached the coast of Portugal

Figure 2.6 The Location of Biscay

Source: https://search.archives.gov/search?query=Prestige by the impact of wind, a black 5 km wide and 37 km long belt of oil pollution formed where the "prestige" passing through. The 19th, "Prestige" broke into two sections and sank to the bottom in 1.5 km depth away from Portuguese waters about 50 kilometers; The 20th, a larger fuel leakage occurred by the sunk tanker. The ship contained 77 thousand tons of fuel oil, more than 6.3 thousand tons of fuel oil of which spilled into the sea eventually. The accident resulted in heavy pollution in hundreds of beaches of 500 kilometers off the coast north of Spain, and killed tens of thousands of seabirds.

Volunteers cleaning the coastline in Galicia in the aftermath of the Prestige catastrophe, March 2003

Figure 2.7 Cleaning of Oi Spill by Volunteers

Source:http://www.emsa.europa.eu/news-a-press-centre/external-news/item/2303-annual-overview-of-marine-casualties-and-incidents-2014.html

On January 17, 2013, the Escort Minesweeper of the Seventh Fleet of United States Navy was grounding in Thuba Taha Reef of northern Philippines Subic port when it was on its way to Puerto Princesa. Tubba Taha Reef National Ocean Park is regarded as one of the best diving sites in Philippines. Tubba Taha Reef was collected in "World Heritage List" published by UNESCO in 1993. It is no doubt that the American warship's grounding damaged large areas of coral reefs, this was a devastating damage to the world's natural coral reef resources.

2.5.3 Randomness and Small Probability

Maritime traffic accident is caused by the undesirable event which is result of the basic elements and conditions which are not coordinated with each other. These elements and conditions are objective existence, and the " undesirable " event caused by which interacted with each other is unpredictable, and thus, the occurrence of accident is random (Gaonkar, R.S.P., 2011). For this reason, the accident must occur in small probability. For example, there had been 984 maritime traffic accidents occurring in China in the year of 1998, and the total freight volume was 1.08 billion tons, that is, the rate of accidents is only 0.009111 per 10000 tons of corresponding freight volume. Therefore, the small probability is also one characteristic of maritime traffic accident.

2.5.4. Regularity

The most significant element of the occurrence of maritime traffic accidents is human error, so the regularity of accident should correspond with the regularity of human. Accident is most easily caused by Fatigue, thus the accident always occurs at night, especially in the middle of the night. Moreover, the maritime traffic accident is the result effected by various elements jointly, the environmental element is also one of the basic elements of maritime traffic accidents, which will have a profound impact on the accidents (Hetherington, C., 2006). Maritime traffic activity is a kind of human activities, and the frequency of maritime traffic activity should be different in different seasons, and thus, the frequency of occurrence of accidents should also be different. To sum up, the regularity of maritime traffic accident is also corresponding with the visibility, season and other environmental elements.

2.6 Concluding Remarks

Pursuant to the above, the research on characteristics analysis and statistics method of maritime traffic accident have made some progress in China that have developed from qualitative statistical to quantitative analysis at present.

Internationally, in order to promote cooperation of maritime traffic accident investigations by countries, a unified survey was conducted, and General Assembly of IMO have adopted numerous conventions, rules, resolutions and recommendations on accident investigations.

In addition, this research paper also introduced three typical accident analysis models in the field of maritime traffic accident analysis. However, most of them are conceptual models which could not achieve the purpose of systematical analysis and targeted relative measures proposing.

According to the statistical method of maritime traffic accidents adopted by Ministry of transport of China, maritime traffic accidents have been divided into ten categorizes by various accident causations, and the accident have been ranked into: minor accident, ordinary accident, major accidents, serious accident, and extraordinarily serious accident. Furthermore, a lot of typical cases were presented in the paper for illustrating the characteristics of maritime traffic accident: huge losses, serious harm, regularity, randomness and small probability.

CHAPTER 3

Maritime Traffic Conditions Analysis of Laotieshan Channel

3.1 Particulars

Laotieshan Channel, as one of the three major channels in China, its position is between Laotieshan in the southwest of Jiangdong Peninsula and Beihuangcheng Island in the north of Miaodao Islands. It is about 22.5 nautical miles wide, except for military restricted areas on both sides of which, and the navigable water area is only 5.5 nautical miles in width. The depth is from 39 meters to 68 meters, which is the deepest and most wide navigable areas in Bohai Strait, and which is also called the "throat" of Bohai Bay. There is a lighthouse in the west corner of Laotieshan, and therefore, vessels can navigate day and night by it. The direction of the channel is northwest - southeast, and the length of which is about 45 km. The deepest position of Laotieshan channel is measured as 83 meters, and the channel contacts Yellow Sea with Bohai Sea in China.

Figure 3.1 The location of Laotieshan Channel.

Source: https://map.google.cn/Laotieshan

In order to separate two opposite directions of vessel traffic flows in Laotieshan Channel, identify the collision avoidance relation and reduce the meeting possibility of vessels. In June 2006, the Ministry of transport of China has announced the formal implementation of ship routing scheme (SRS) and ship reporting scheme (SRS) in Laotieshan Channel, and a 9 nautical miles long and 1 nautical mile wide separation area in the middle of the navigable areas has separated which into two parts, each one is 2.25 nautical miles wide. The direction of eastbound ships is 120 degrees, and 300 degrees for westbound ships (the true course). There are some complex vessel traffic flows meeting in Laotieshan Channel from the directions of Tianjin, Qinhuangdao, Jinzhou, Jingtang， etc. In order to avoid the maritime traffic accidents happening in this area, a warning zone was set up in the northwest end of the separation area which is a circle with the center (38° 34. 40'N, 120° 51. 30' E), and 5 nautical miles as the radius (Wang, J. D., 2009).

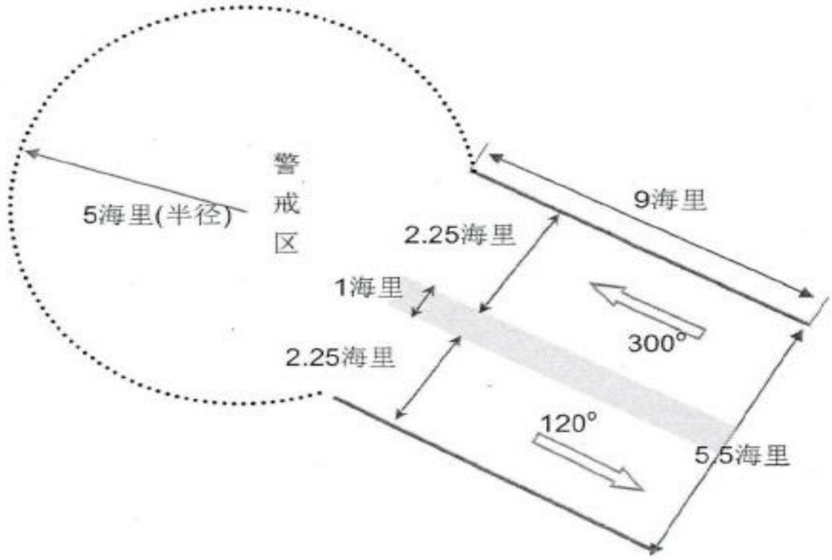


Figure 3.2 Particulars of Navigable Area in Laotieshan Channel.

Source: Liang, Q.H. Research on Ship Routing Scheme in China, 2010.

Table 3.1 Particulars of Navigable Area in Laotieshan Channel.

Particulars	Figure
The width of channel in total	22.5 nautical miles
The depth of water in channel	39 to 68 meters
The direction of the channel	northwest – southeast
The length of channel in total	45 kilometers
The width of navigable areas	5.5 nautical miles
The length of separation area	9 nautical miles
The width of separation area	1 nautical mile
Direction for eastbound vessels	300 degrees
Direction for westbound vessels	120 degrees
The center of warning zone	38° 34. 40'N, 120° 51. 30' E
The radius of the warning zone	5 nautical miles

Data source: Liu, G.C. Implementation of Ship Routing Scheme in China, 2010.

3.2 Natural Condition

According to the existing nautical publications recorded: Laotieshan Channel is affected by the monsoon obviously, South and southwest wind prevail in the 4-5 month every year, and the wind force of which is 3-5 degree generally. When the southwest wind is generated by the north depression, that will be stronger. The East and southeast wind prevail in the 6-8 month, the force of which is always below 6. The cold wave acts frequently in Winter, so the force of north wind often reaches 6-8. When the northerly wind with 6 force or above occurs, the surge accompanying will be larger.

The northerly wind with 6 force or above which is most likely to occur in January, which usually lasts as long as 25 days or so. The typhoon impacts on the channel occasionally, but the center of strong winds rarely passes through the channel. When typhoon strikes, the largest wind in the water area is 11 force. Moreover, there are many foggy days in Laotieshan Channel every year, the average of which is about 44 days. It occurs nearly every month, the longest duration of which mostly from March to August, and sometimes lasts 3-4 days in June and July especially. In addition, the directions of currents in Laotieshan Channel are: the westbound current begins about one hour before the high tide of Dalian water area, and ends about 1 hours before the low tide; the eastbound current begins about one hour before the low tide of Dalian water area, and ends about 1 hours before the high tide. The velocity of the current is about 2-3 nautical miles one hour, the maximum of which could reach 6.25 (Zhang, H., 2016). Therefore, the weather and hydrologic conditions of Laotieshan Channel is complex and changeable, sometimes that will bring great threat to the maritime safety, which makes the channel where the maritime traffic accident occurs frequently. Figure shows the number of days in strong wind, poor visibility and rough sea monthly in the year of 2015.

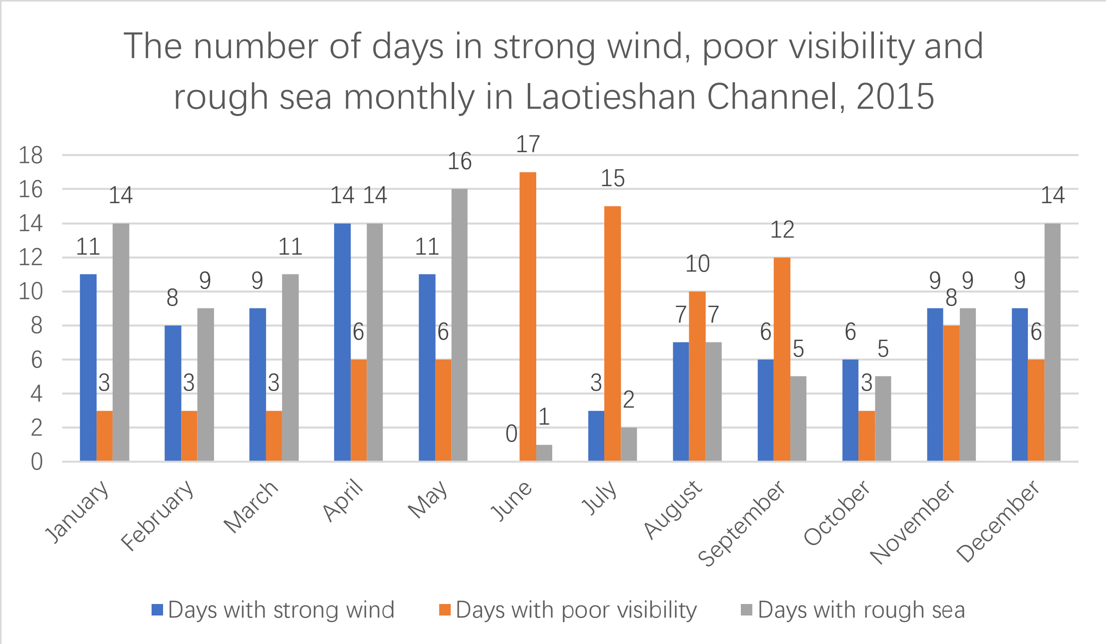


Figure 3.3 The Number of Days in Strong Wind, Poor Visibility and Rough Sea Monthly in Laotieshan Channel, 2015.

Data source: Zhang, H. Research on maritime safety management planning in Laotieshan Channel, 2016.

3.3 Track Distribution

Both of Laotieshan Channel and Dachangshan Channel are the major channels for entering or leaving Bohai Bay currently. And more than 70% of the freight volume is transported by Laotieshan Channel, which mainly collects the traffic flows from the direction of Yingkou, Qinhuangdao, Tianjin, Huludao, and Jingtang Port (Figure 3.4). At present, the military restricted zones are set on the both sides of Laotieshan Channel that makes the ship traffic flow pass through the Laotieshan channel in 22.5 nautical miles width originally, but which has been concentrated into 5.5 nautical miles wide now. Since the implementation of the ship routing scheme, 1 nautical mile in width is occupied by the separation area in the middle of the channel, and the two navigable waterways on each side is 2.25 nautical miles wide respectively. Because of the relatively complicated vessel traffic flows on the west side of the Laotieshan channel, a navigational warning zone with a radius of 5 nautical miles is set on the western channel.

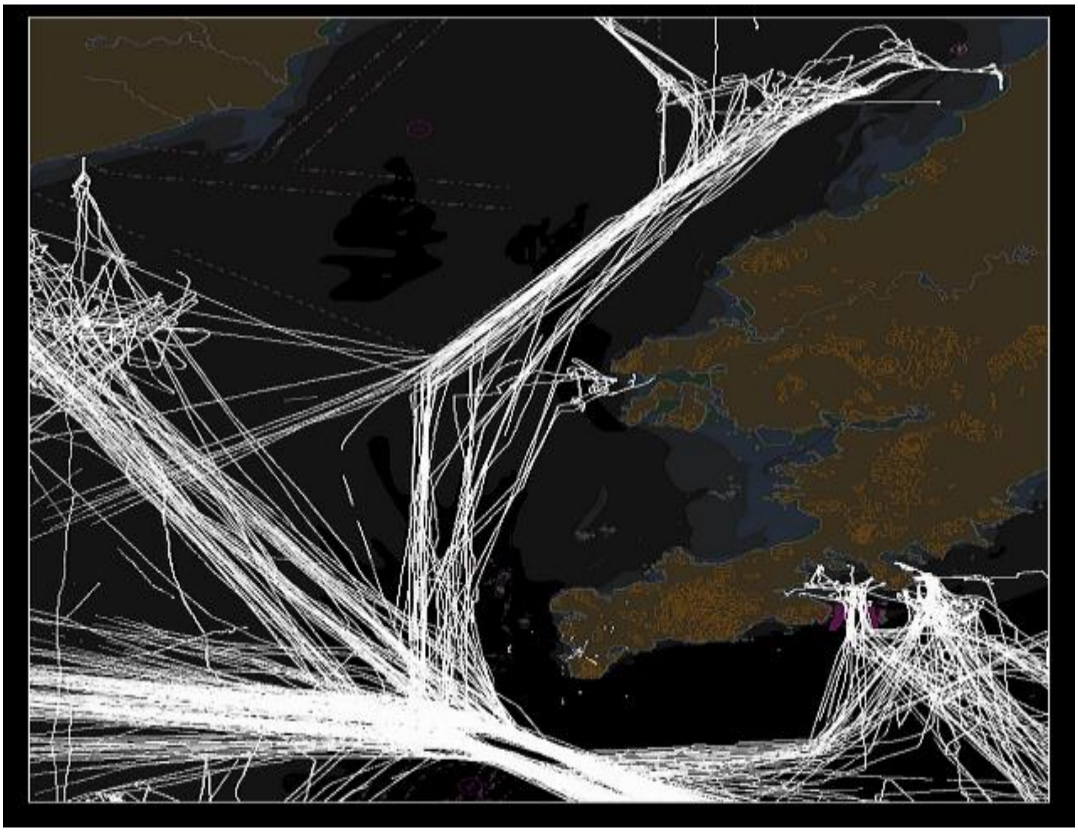


Figure 3.4 Track Distribution of Vessels in Laotieshan Channel.

Source: Wan, H. Survey and analysis of vessel traffic flow in Laotieshan Channel, 2015.

According to the statistics, the direction of vessel traffic flow entering and leaving Laotieshan Channel is vertical with the direction of passenger ships and train ferries sailing between Dalian and other ports in Bohai Bay basically. For Laotieshan Channel, it is only 5.5 nautical miles wide, and there are nearly 280 merchant ships passing through the channel every day, so the traffic density is quite large. In addition, according to the data recorded by Dalian VTS center, there are approximately 6000 vessels across the Laotieshan Channel every year, 4617 times of passenger ships in 2016. At present, there are a total of 25 passenger ships managed by shipping companies in Dalian sailing between Liaoning Province and Shandong Province, by which it can be calculated in the next 5 years the total times of passenger ships passing through the channel will be approximate 19000 (Wan, H., 2015). Furthermore, due to the large number of fishing boats operating, sailing and parking in Laotieshan Channel and the nearby water areas, and most of which always do not comply with the maritime regulations that would increase the complexity of tracks in the channel to some extent. Thus, it can be predicted that maritime safety issues will be more and more serious.

3.4 Vessel Speed

With the implementation of ship routing scheme in Laotieshan Channel in 2011: when the ship is sailing in Laotieshan Channel, the speed of which should not exceed 16 knots; if the visibility is less than 1 nautical mile, the speed of vessels should not exceed 12 knots; if the visibility is less than 1000 meters, the speed should not exceed 10 knots. The regulation effectively decreased the average speed of ships.

According to the ship speed records provided by Dalian Maritime Safety Administration in 2015, which has analyzed the speed distribution of vessels entering and leaving Laotieshan Channel, the regularity of ship's speed distribution in 2015 has been obtained. The average speed of westbound ships in 2015 was 11.9 knots, and the average speed of eastbound ships was 11.4 knots. Most of the ships' speed followed the normal distribution regularity.

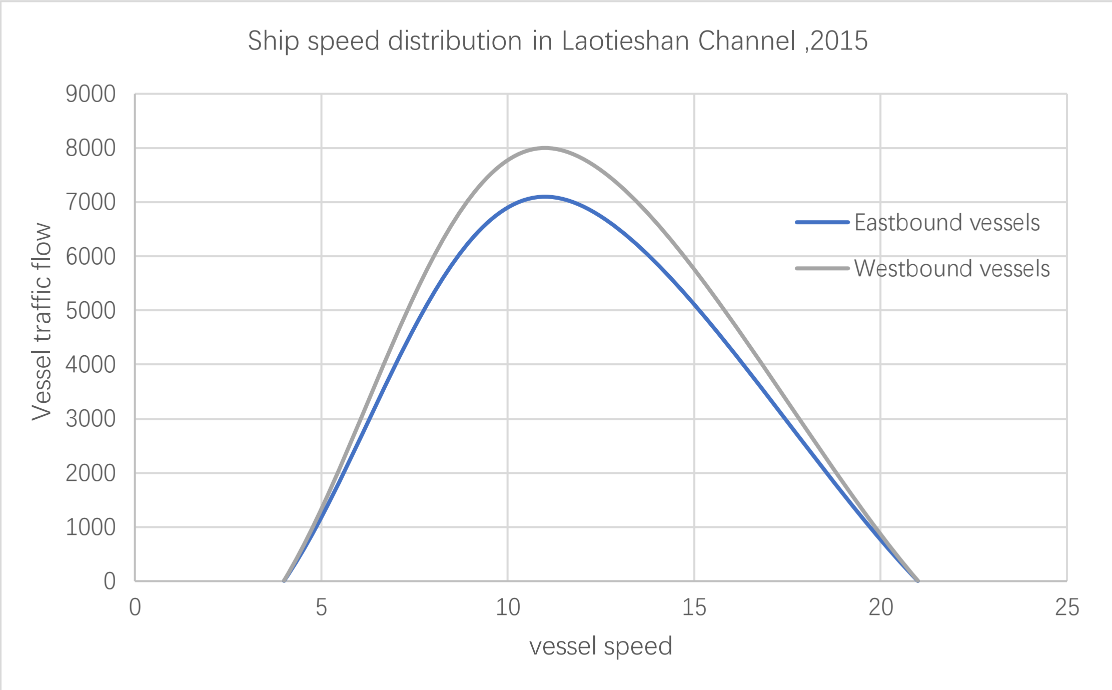


Figure 3.5 Ship Speed Distribution in Laotieshan Channel 2015.

Data source: Ji, K.P. Introduction of Special Regulations of Laotieshan Channel, 2016.

Which can be seen from the Figure 3.5 that the ships' speed is mainly between 10 to 13 knots in 2015, there are some differences of speed between the eastbound vessels and the westbound vessels, which is mainly because most of eastbound vessels are overloading, otherwise, the westbound vessels are always no-loading, the westbound vessels are more fast than eastbound ones relatively.

3.5 Vessel Traffic Flow

There was a total number of 84799 times of ships passing through the Laotieshan Channel in 2014, including 42422 times of eastbound vessels and 42367 for westbound vessels. The monthly average of vessel traffic flow (VTF) was 7066 times and the daily average was 232 times in 2014, in which monthly 3535 times and daily 116 times for eastbound vessels, monthly 3531 times and daily 116 times for westbound vessels (Wan, H., 2015).

Table 3.2 Statistic of Vessel Traffic Flow in Laotieshan Channel, 2014.

Statistics of vessel traffic flow	Times
Total in 2014	84799
Eastbound vessels in total	42422
Westbound vessels in total	42367
Monthly average of times in total	7066
Daily average of times in total	232
Monthly average of eastbound vessels	3535
Daily average of eastbound vessels	116
Monthly average of westbound vessels	3531
Daily average of westbound vessels	116

Data source: Wan, H. Survey and Analysis of Vessel Traffic Flow in Laotieshan Channel, 2015.

As we can see from the Figure 3.6, the monthly distribution of ship traffic flow was not quite balanced. It was relatively low in February and July, however, the traffic flow approached the maximum in June. The traffic flow remained in relatively stable from August to November.

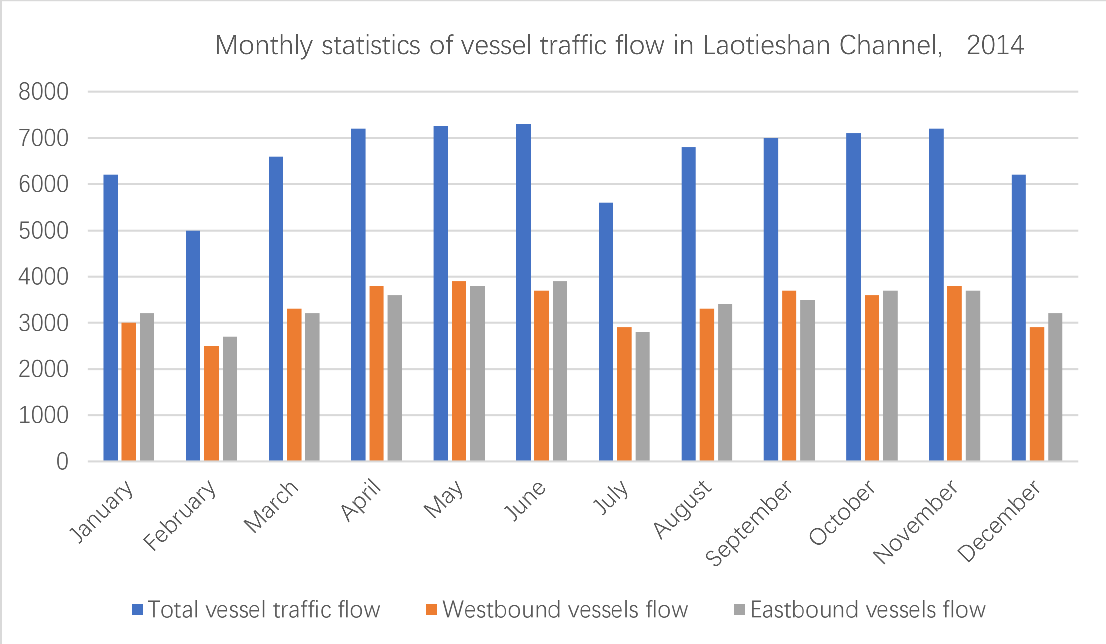


Figure 3.6 Monthly Statistics of Vessel Traffic Flow in Laotieshan Channel, 2014.

Data source: Wan, H. Survey and Analysis of Vessel Traffic Flow in Laotieshan Channel, 2015.

According to incomplete statistics additionally, there are almost 130 thousand times of fishing boats operating in Laotieshan channel and water areas nearby every year, and there are about more than 400 times daily.

3.6 Ship Type

According to the statistics of ships' type in Laotieshan Channel in 2014, the largest proportion of ship is the bulk carrier. Through the systematic analysis of various types of cargo ships, we can have a better knowledge of the maritime regularity of ships in the channel.

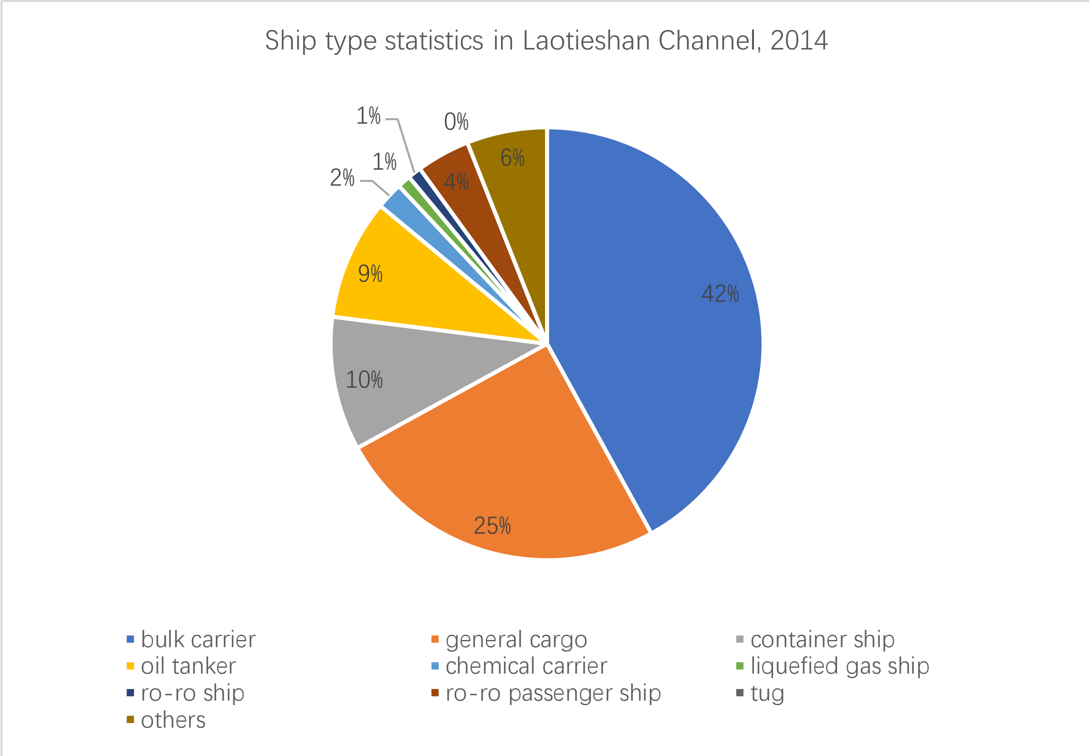


Figure 3.7 Ship Type Statistics in Laotieshan Channel, 2014.

Data source: Zhao, N. Research on Bearing capacity of Laotieshan Channel, 2015.

As can be seen from Figure 3.5.1, the total number of cargo ships accounted for the vast majority of ships passing through the channel. Among them, the bulk carriers accounted for 42%, 25% of general cargoes, container ships accounted for 10%, oil tankers accounted for 9%, chemical carriers and liquefied gas ships accounted for 2% and 1% respectively, and 4% of the ro-ro passenger ships, thus, dry bulk cargo (including bulk carriers and general cargoes) accounted for 67% totally, liquid cargo ships (including oil tankers, chemical carriers and liquefied gas ships) accounted for 12% in total, and 10% for the container ships (Zhao, N., 2015).

At present, the bulk carrier, container ship, oil tanker and dry cargo ship are the main types of ships passing through the Laotieshan Channel. Although the bulk chemical tankers, liquefied gas carriers and oil tankers do not have a large proportion of all ships, the number of which in the channel still could be large. Once an accident of the vessel occurs, it will cause great economic losses and ecological environment harm.

Moreover, the trend of large-size ships passing through Laotieshan Channel becomes obvious. Aframax tanker and VLCC are more popular for ship-owners, the number of oil tankers in Aframax, Suezmax and VLCC will be increased steadily. The development of large-size container ship is still strong, the container ships of 10000TEU in Maersk, COSCO, China shipping and CMA CGM shipping companies have been put into use gradually. In addition, ships in Handysize, Panamax and Capesize will be main types of bulk carriers, the load capacity of which accounted for 3/4 of the bulk carriers in total. Besides, VLOC with more than 200 thousand tons load capacity will become the new force of ore transportation.

3.7 Ship Route

At present, the major routes of vessels entering Laotieshan Channel is to Qinhuangdao, Tianjin, Boyuquan, and Jingtang port. Through the statistics of ship routes in Laotieshan Channel in 2014, we can get the routes distribution of ships in Laotieshan Channel.

From Figure 3.8, Qinhuangdao and Tianjin are two major routes which account for 26% and 23% of the total vessel traffic flows respectively, Bayuquan accounts for 17% which is the third place. The following ports is Jingtang Port for 10%, Jinzhou port for 7% and Caofeidian port for 5%. According to the track distribution analysis and vessel traffic flow analysis before, Tianjin port, Qinhuangdao port and Bayuquan port are the routes with the three of the largest vessel traffic flows, which accounted for 66% in total (Xing, Y.H., 2015). Moreover, for the ships sailing to Jinzhou port, Huludao port and Yingkou port, the same route they would use with ships to Boyuquan port in Laotieshan channel. The route to Suzhong port is the same as that to Qinhuangdao. The ship sailing to Jingtang and Caofeidian port would use the same route of which to Tianjin port. Therefore, the routes to these areas mentioned above have covered more than 90% of the customary routes of vessels in the channel.

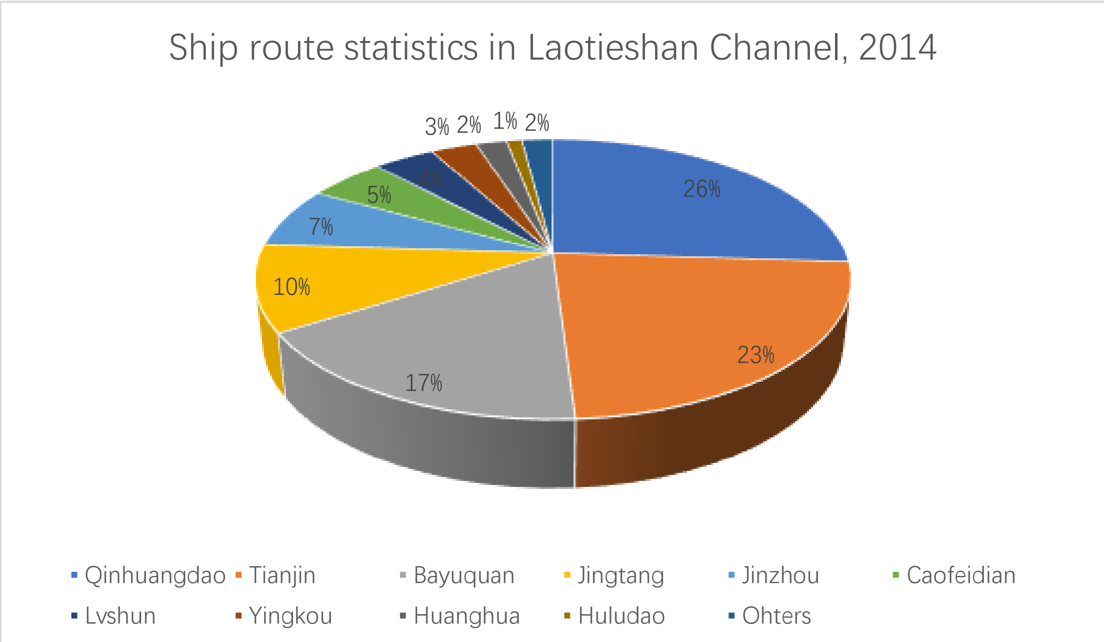


Figure 3.8 Ship Route Statistics in Laotieshan Channel, 2014.

Data source: Xing, Y. H., Research on performance assessment of Laotieshan Channel, 2015.

3.8 Concluding Remarks

Laotieshan Channel, as one of the most important channel in northern China, a large number of vessels entering and leaving Bohai Bay by which every year. Since 2006, the implementation of ship routing scheme, the vessel traffic flow in which has been divided into two directions – east and west by the separation area. However, maritime traffic accidents occur frequently due to the complex traffic conditions of Laotieshan Channel. This chapter has analyzed the maritime traffic conditions of the channel from the aspects of natural condition, track distribution, ship speed, vessel traffic flow, ship type and ship route. The major results of summary and analysis are:

a. Strong wind and rough sea influence the maritime condition occasionally;

b. The major vessel traffic flows are consisted of vessels from Yingkou, Qinhuangdao, Tianjin, Huludao, Jingtang and other ports;

c. Bulk carrier and general cargo ship are the most common ship type used for transportation in the channel.

CHAPTER 4

Maritime Risk Prejudgment of Laotieshan Channel

Laotieshan Channel is an important part of Dalian waters, which located in the northern of Bohai Strait, connecting Bohai sea and Yellow Sea. Laotieshan Channel is the northernmost and widest channel of Bohai Strait. Laotieshan Channel is an important path for vessels entering and leaving China's northern ports: Tianjin port, Qinhuangdao port and others. The maritime traffic accident occurs frequently due to the swift current and complicated navigational conditions.

This chapter has divided Laotieshan Channel into 4 navigable sea areas: traffic separation area， inshore traffic zone， warning zone and other sea areas nearby. By introducing vessel traffic conflict theory, the chapter would offer the maritime risk prejudgment for these 4 sea areas of Laotieshan Channel, by which the areas could be recognized as safe, generally safe and unsafe.

4.1 Vessel Traffic Conflict Theory

4.1.1 Definition

Two or more ships in a certain time and space are close to each other to a certain extent, if at this time they does not change their states of motion, there will be an accident risk of collision, which is called Vessel Traffic Conflict (VTC). The vessel traffic conflict also can be expressed as: a traffic encountering incident that the deck officer obviously feels the risk of accident, and then take positive and effective avoidance action. The vessel traffic conflict method is a kind of technical measurement on the basis of a certain method or criteria to identify and evaluate the process and severity of the accident, which is applied to make a risk assessment and safety improvement (Tan, J., 2011).

4.1.2 Vessel Traffic Conflict and Close-quarters Situation

Close-quarters Situation is a very important concept in the process of vessel collision avoidance, it means when two ships approach to each other, only the action of one vessel could not lead to passing at a safe distance (Qiao, M., 2009). The Close-quarters situation has the following basic characteristics:

a. The ship is in the geometric collision meeting situation, or has not yet gotten rid of the situation;

b. The uncertainty of ship collision avoidance is obviously higher than that in the usual situation;

c. The ship is close to the extent of no sufficient time or space for collision avoidance decisions and operations.

The similarities between the two: the concepts of VTC and close-quarters situation look the same to some extent, in fact the close-quarters situation mentioned above in the field of ship is the maritime traffic conflict, and the collision risk reflects the severity of maritime traffic conflict, one close-quarters situation is a serious maritime traffic conflict.

The differences between the two: the concept of close-quarters situation is mostly from the microscopic angle of single vessel or multi vessels, which has not yet reached to the extent of local maritime traffic flow to be researched. At present, the research of ship collision avoidance and close-quarters situation mainly focuses on the collision avoidance of two ships, which belongs to the microscopic sector. Based on the data collection of micro close-quarters situation, it is focused on the study of vessel traffic conflict in a certain water area that belongs to the meso sector. In a word, the traditional research of ship collision avoidance is“point to point”, but vessel traffic conflict theory and technology research based on close-quarters situation is "line to line".

4.1.3 VTC Generation Mechanism

In routine maritime accident analysis, human errors are usually considered as the most important reason of accident (Chen, S.T., 2012). However, in the process of a maritime traffic accident generation, the other factors should not be ignored except for human errors. The factor alone may not provide the obvious impact, but the maritime traffic safety will be more seriously impacted by them together. Similar to maritime traffic accidents, vessel traffic conflicts are caused by a variety of complex factors that lead to the occurrence of the conflict which are intrinsically linked to the number of vessel traffic conflicts, conflict rate and conflict intensity.

4.1.4 VTC Generation Process

In a maritime traffic system, the operation state of this will be changed continuously due to person, machine, environment, management and other factors. If this change is caused by traffic incidents, the unsafe state of maritime traffic will be shown, which is transformed under specific time and space conditions and then generates an accident. Traffic flow design, waterway design, traffic control method, traffic condition and operation behavior will all impact on the operation performance of the ship. They are combined and interacted with each other to generate the vessel traffic conflict. Vessel traffic conflicts are usually concentrated in the intersections of ship routing system, traffic-intensive areas and other junctions of multi-vessel flow. For the intersections in ship routing system, traffic-intensive areas and other junctions of multi-vessel flow as a system, it is possible to generate a vessel traffic conflict by changing any one of the factors in the system. When the number of collisions and conflicts increases in the system, the accident risks of the system will also exist.

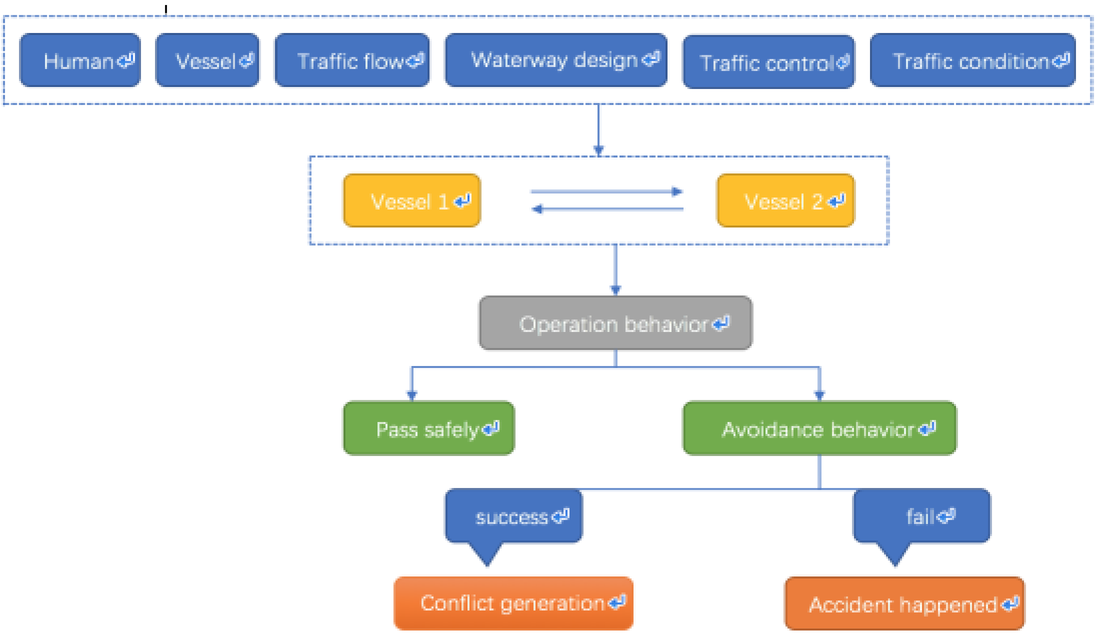


Figure 4.1 VTC Generation Process.

Source: Tan, J. The application of the safety of ship collision avoidance on traffic conflicts technique, 2011.

The VTC generation process is shown in Figure 4.1. The ship barrier-free is measured by the ship state without any interference outside. Generation of vessel traffic conflict is mainly manifested on the requirement for the ship to take slowing down, steering and other corresponding measurements in time to pass safely. Vessel Traffic conflict can also be described in detail as a process of which two vessels in relative motion in a certain time, approach to the accident contact point at the same time. The special variation relation of time and space could be described as time, distance, speed and other variables.

4.2 The Relation Between Vessel Traffic Conflict and Maritime Safety

4.2.1 Maneuvering Behavior

Human is the main part of the maritime traffic system, and all the contents of the maritime traffic are associated with various kinds of human behavior (Macrae, C., 2009). The maneuvering behavior is a reflection of the characteristics of ship maneuverability, in addition to which is the result impacted by various external factors. Because of the difference of characters of crews and the environment, that will result in different crews having different cognitive on the same thing. Such as when ships are in the meeting situation, crews with different types of temperament always illustrate different actions. As in a traffic-intensive area, the crews with different types of temperament will have various performance on controlling the ship. At that time, the crews will take over more complicated information, if who lacks experience of dealing with the situation timely and effectively, which will cause deviation and fault of maneuvering behavior, and then lead to a traffic conflict, even an accident.

4.2.2 Vessel Traffic Flow

The different characteristics of vessel traffic flow could lead to various traffic conflicts. Among the numerous characteristics of ship traffic flow impacting on maritime traffic, the quantity of the traffic flow plays a quite important role. With the increase of traffic flow, traffic conflicts and emergencies also increase, which seriously interfere with the maritime safety in the channel. The number of traffic conflicts is not only related to the quantity of traffic flow, but also to the ship type, traffic flow direction and the number of traffic flows in different directions. When the quantity of traffic flow is constant and equal in each direction, the number of traffic conflicts and collision points will peak to the most.

4.2.3 Environmental Condition

The impact of weather on maritime safety is serious, which mainly lies in the loading conditions of environment for wind, wave and current, visibility (Mazaheri, A., 2012). The poor weather condition will have a great adverse impact on the maritime safety such as cargo shifting, stability loss, hogging and sagging, etc. which is mainly embodied on the hull and equipment damage. However, due to the implementation of traffic control and other measures, vessel traffic conflicts will be greatly reduced.

In the case of poor visibility, the ship collision accident accounts for a large proportion of all ship collision accidents, and the poor visibility will bring adverse effects to detect the collision risk timely and take corresponding measures. Therefore, the poor visibility plays an important role in the generation and development of vessel traffic conflicts. It is easy to generate vessel traffic conflicts due to poor visibility, and then develop into maritime traffic accidents.

4.2.4 Maritime Accident

To some extent, both of maritime traffic accident and vessel traffic conflict belong to one category that is the performance of unsafe traffic factors. The causes and generation process of them are quite similar, and the only difference between which is if there is some damage (Psaraftis, H.N., 2012). The development of vessel traffic conflict may lead to accidents happening, but which also could be avoided by taking collision avoidance action properly. In other words, the vessel traffic incident results in casualties or ship loss which is called a maritime traffic accident. otherwise that is known as a vessel traffic conflict. The vessel traffic conflict is a potential factor of the accident, especially for the serious conflict and that has the strong correlation with the traffic accident. Vessel traffic conflict technology is not only an alternative method of accident statistics, but also avoids the shortage of accident statistics to a certain extent.

4.3 Application of Vessel Traffic Conflict Theory in Maritime Risk Prejudgment of Laotieshan Channel

The conflict rate (the ratio of number of conflicts per unit time and vessel traffic flow, VTCR) has been used as an index in maritime risk prejudgment, which is denoted as VTC/VTF. Through the data collection of traffic conflicts, and then the technique could be used to give a quantitative analysis on safety status of the object. That will solve the drawbacks due to the lack of data of the accident to a certain extent (Lu, C., 2010), which shows the applicability of vessel traffic conflict theory and technology for a certain water area.

4.3.1 Prejudgment Method

The core principle and route of maritime traffic conflict technique applied to the risk prejudgment is: based on the data of vessel traffic conflicts collected in the sea area, and taking the number or rate of the conflicts as the index, the main measure is calculating and comparing the value of index to provide the risk prejudgment for maritime safety in the sea area, or using specific system engineering analysis method to analyze the maritime traffic conflict data collected to quantitatively describe the status of maritime safety. Several methods are introduced as follows:

a. Taking the number of vessel traffic conflicts as an index, through comparing the number of absolute conflicts collected within a certain time, then the status of maritime safety in different ranking would be obtained.

b. Taking the actual vessel traffic conflict rate as the index, the impact of the number of vessel traffic conflicts and actual vessel traffic flows that should be taken into account for selection and determination of the index. Usually selecting daily vessel traffic conflict rate as an index, and by comparing the values of index in addition, the traffic safety status will be qualitative and quantitative estimated.

c. Still taking the conflict rate as the index, the influence of different severity of the conflict should be taken into consideration on the maritime safety, and adopting a certain mathematical method to deal with the index, finally a risk prejudgment result will be obtained. This method is more scientific in the processing of risk prejudgment index, which is the key research method in this paper.

4.3.2 Establishment of Prejudgment Model

a. Selection of the method

Using vessel traffic conflict rate as an index for maritime risk prejudgment is the thought of maritime safety research by traffic conflict technique, the basic requirement of which is to be able to obtain corresponding data of vessel traffic conflict and vessel traffic flow effectively. However, it is found that the number of serious conflict samples collected is usually very small, which cannot meet the requirements of data analysis and processing. Additionally, a large number of non-serious conflict samples are lied idle. In fact, both of them as the characterization of maritime safety status, the only difference between serious conflict and non-serious conflict is the various correlation with them, but both of them could be used as an effective index for risk prejudgment. Therefore, the serious conflicts and non-serious conflicts are taken as the basis of risk prejudgment, the index should be used to represent the maritime safety status as much as possible.

b. Selection of prejudgment indexes

Due to the dynamic characteristics of vessel traffic flow and maritime safety status in the Laotieshan Channel, the number of vessel traffic conflicts represents the absolute maritime safety status of the water area. Therefore, the number of vessel traffic conflicts and the quantity of vessel traffic flow are chosen as the prejudgment source data, and the ratio of which is used as the prejudgment index.

The collected data are marked as the non-serious vessel traffic conflict (VTC1) and serious vessel traffic conflict (VTC2). According to the data of vessel traffic flow (VTF) and vessel traffic conflict in the channel, VTC1/VTF and VTC2/VTF of peak time and flat time are obtained respectively, which will be regarded as prejudgment index. In this way, for a certain sea area, the status of maritime safety and vessel traffic flow can be basically reflected by the 4 index:

Table 4.1 Maritime Safety Status Index

Non-serious vessel traffic conflict	VTC1
Serious vessel traffic conflict	VTC2
Non-serious vessel traffic conflict rate	VTC1/VTF
Serious vessel traffic conflict rate	VTC2/VTF

Source: Author.

c. Establishment of prejudgment matrix

According to the data collected of vessel traffic conflict and vessel traffic flow in Laotieshan Channel, the initial prejudgment matrix D could be obtained, D_{ij} in which is the element in the sample matrix, prejudgment object i∈{l, 2,..., n}, prejudgment index j∈{l, 2,..., m}, and the prejudgment matrix could be represented as:

$$D = \begin{bmatrix} d_{11} | d_{12} \ldots d_{1m} \\ d_{21} | d_{22} \ldots d_{2m} \\ \cdots \; \cdots \; \cdots \; \cdots \\ d_{n1} | d_{n2} \ldots d_{nm} \end{bmatrix}$$

In this paper, the mathematical probability statistics method is mainly used for classification of safety status of various water areas into excellent, medium and poor by means of frequency cumulative curves. Selection of 15%, 50% and 85% corresponding λ_1 、 λ_2 and λ_3 in the frequency cumulative curve, then various functions of which are established. The purpose of establishment of the function is used for classification of the value of the determined index j into safe, generally safe and unsafe. For the index j, the functions of which in classification of safe, generally safe and unsafe could be represented as the frequency cumulative curves $f_3(x)$ 、 $f_2(x)$ 、 $f_1(x)$ respectively in Figure 4.2

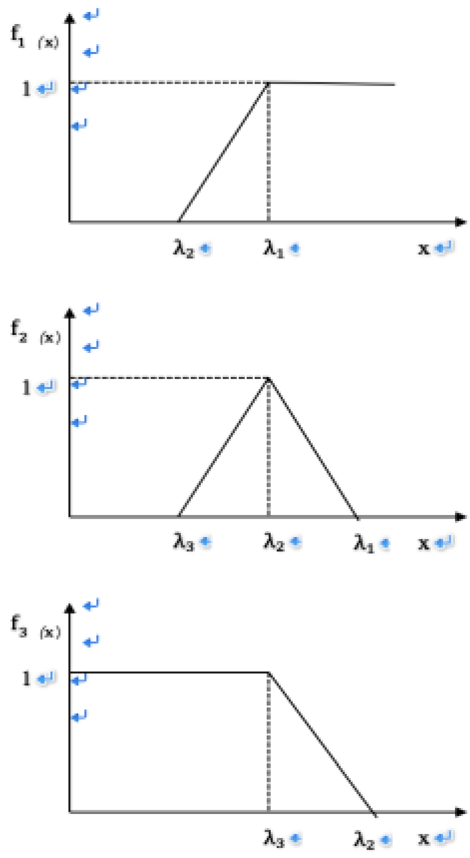


Figure 4.2 Frequency Cumulative Curve $f_3(x)$、 $f_2(x)$ 、 $f_1(x)$.

Source: Author.

The corresponding functions of frequency cumulative curves $f_1(x)$, $f_2(x)$, $f_3(x)$ are:

$$f_{1(x)}\begin{cases} 0, x < \lambda_2 \\ \dfrac{x-\lambda_2}{\lambda_1-\lambda_2}, x \in [\lambda_2, \lambda_1] \\ 1, x \geq \lambda_1 \end{cases}$$

$$f_{2(x)}\begin{cases} 0, x \notin [\lambda_3, \lambda_1] \\ \dfrac{x-\lambda_3}{\lambda_2-\lambda_3}, x \in [\lambda_3, \lambda_2] \\ \dfrac{\lambda_1-x}{\lambda_1-\lambda_1}, x \in [\lambda_2, \lambda_1] \end{cases}$$

$$f_{3(x)}\begin{cases} 0, x > \lambda_2 \\ \dfrac{\lambda_2-x}{\lambda_2-\lambda_3}, x \in [\lambda_3, \lambda_2] \\ 1, x < \lambda_3 \end{cases}$$

4.3.3 Maritime Risk Prejudgment of Laotieshan Channel

Through the long-term of related data collection in Laotieshan channel and the sea areas nearby, the real-time classification and statistics of severity of vessel traffic conflict for 1 day (24 hours) have been obtained. Taking 0600-1800 as the peak time, 0000-0600 and 1800-2400 as the flat time of vessel traffic flow, the data of vessel traffic flow and conflict at the peak time and flat time collected are shown in the following Table 4.2.

Table 4.2 Classification and Statistics of Severity of Vessel Traffic Conflict.

Objects	VTF		VTC1	VTC2	VTC1/VTF	VTC2/VTF
Warning zone	Peak time	115	40	31	0.348	0.274
	Flat time	58	23	15	0.397	0.259
Traffic Separation area	Peak time	78	51	28	0.654	0.359
	Flat time	48	34	19	0.708	0.396
Inshore traffic area	Peak time	24	14	27	0.583	1.125
	Flat time	16	9	17	0.563	1.062
Sea areas nearby	Peak time	18	6	4	0.333	0.222
	Flat time	13	4	2	0.307	0.154

Source: Author.

According to the results calculated by the table above, the matrix of risk prejudgment could be established by using 4 values which is VTC1/VTF at the peak time, VTC1/VTF at the flat time, VTC2/VTF at the peak time, VTC2/VTF at the flat time respectively.

$$D = \begin{bmatrix} 0.384 & 0.274 & 0.397 & 0.259 \\ 0.654 & 0.359 & 0.708 & 0.396 \\ 0.583 & 1.125 & 0.563 & 1.062 \\ 0.333 & 0.222 & 0.307 & 0.154 \end{bmatrix}$$

Based on the frequency cumulative curve of the data in each column, the results are needed to be introduced into the corresponding functions, finally, we could get the risk prejudgment result of maritime safety status of the warning zone, traffic separation area, inshore traffic area and other sea areas nearby in Laotieshan Channel:

a. Warning zone, $f_{2(x)} > f_{3(x)} > f_{1(x)}$;

b. Traffic separation area, $f_{1(x)} > f_{2(x)} > f_{3(x)}$;

c. Inshore traffic area, $f_{1(x)} > f_{2(x)} > f_{3(x)}$;

d. Other sea areas nearby, $f_{3(x)} > f_{1(x)} > f_{2(x)}$.

Therefore, the corresponding description of the maritime risk prejudgment result of Laotieshan Channel is shown in Table 4.3.

Table 4.3 Maritime Risk Prejudgment Result of Laotieshan Channel.

Navigable sea area	Prejudgment result	Description
Warning zone	$f_{2(x)} > f_{3(x)} > f_{1(x)}$	Generally safe
Traffic separation area	$f_{1(x)} > f_{2(x)} > f_{3(x)}$	Unsafe
Inshore traffic area	$f_{1(x)} > f_{2(x)} > f_{3(x)}$	Unsafe
Other sea areas nearby	$f_{3(x)} > f_{1(x)} > f_{2(x)}$	Safe

Source: Author.

4.4 Concluding Remarks

This chapter has analyzed and processed the data of vessel traffic flow and vessel traffic conflict of Laotieshan Channel that based on water traffic conflict theory and relative mathematical probability statistics method. Laotieshan Channel has been divided into 4 navigable sea areas for prejudgment, taking the conflict rate as the index and the impact of various severity conflicts on maritime safety has been considered. According the risk prejudgment model established, the maritime risk prejudgment result of various navigable sea areas of Laotieshan Channel could be obtained finally:

a. Warning zone, $f_{2(x)} > f_{3(x)} > f_{1(x)}$, therefore, the result of which is generally safe;

b. Traffic separation area, $f_{1(x)} > f_{2(x)} > f_{3(x)}$, the result is unsafe;

c. Inshore traffic area, $f_{1(x)} > f_{2(x)} > f_{3(x)}$, it is unsafe as well;

d. Other sea areas nearby, $f_{3(x)} > f_{1(x)} > f_{2(x)}$, thus, which could be regard as safe.

The maritime risk prejudgment of Laotieshan Channel could be used as a reference for accident characteristics and causation analysis in the following chapters.

CHAPTER 5

Accident Characteristics and Causation Analysis of Laotieshan Channel

5.1 Characteristics Analysis of Accident in Laotieshan Channel

5.1.1 In Various Accident Ranking

From 2006 to 2015, there were 47 maritime accidents occurred in Laotieshan Channel, with 37 people dead, 40 ships sinking and 112 million RMB of direct economic losses in total. Among these 47 maritime traffic accidents, there were 33 minor accidents, 11 ordinary accidents, 2 major accidents and 1 serious accidents. Minor accidents were accounted for 70% of the total number of accidents, ordinary accidents accounted for 24% of all, major accidents and serious accidents accounted for 4% and 2% of the total number of accidents respectively.

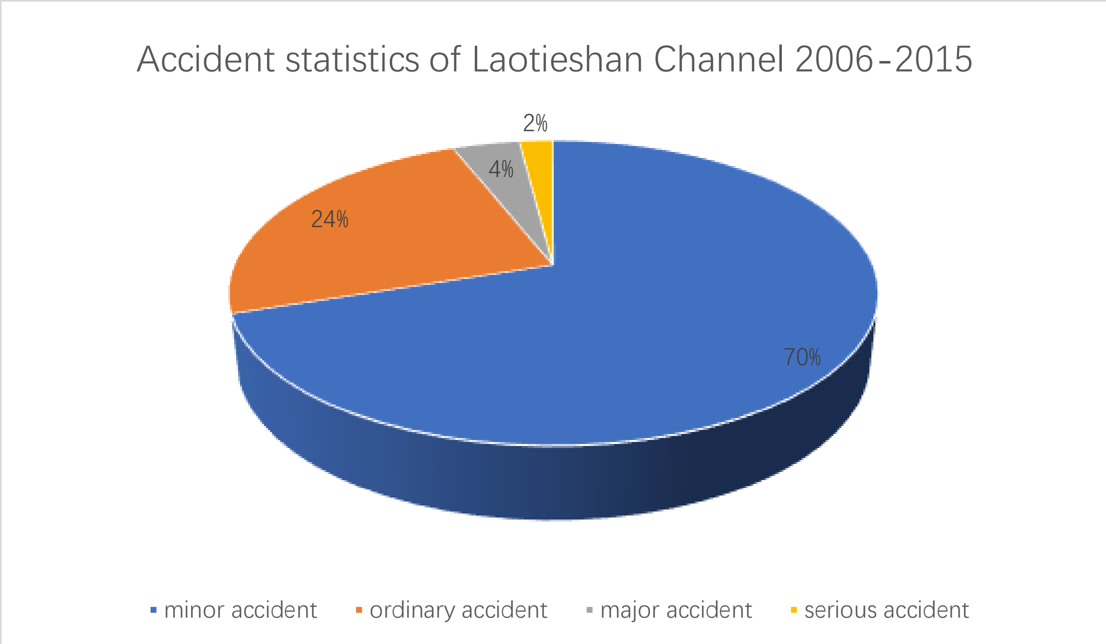


Figure 5.1 Accident Statistics of Laotieshan Channel 2006-2015.

Data source: Dalian MSA. Statistics of maritime traffic accident in Dalian sea areas, 2016.

From Figure 5.1 we can see that the number of the minor accidents was the largest one of all, which accounted for 70%, while the number of ordinary accidents were relatively few that accounted for 24% of all. The major accidents and serious accidents occurred rarely but which should not be ignored, for there were still 4% and 2% respectively of all. We will use the trend line of Excel to analyze the maritime traffic accidents in various ranking and identify the regularity and characteristics of which from 2006 to 2015.

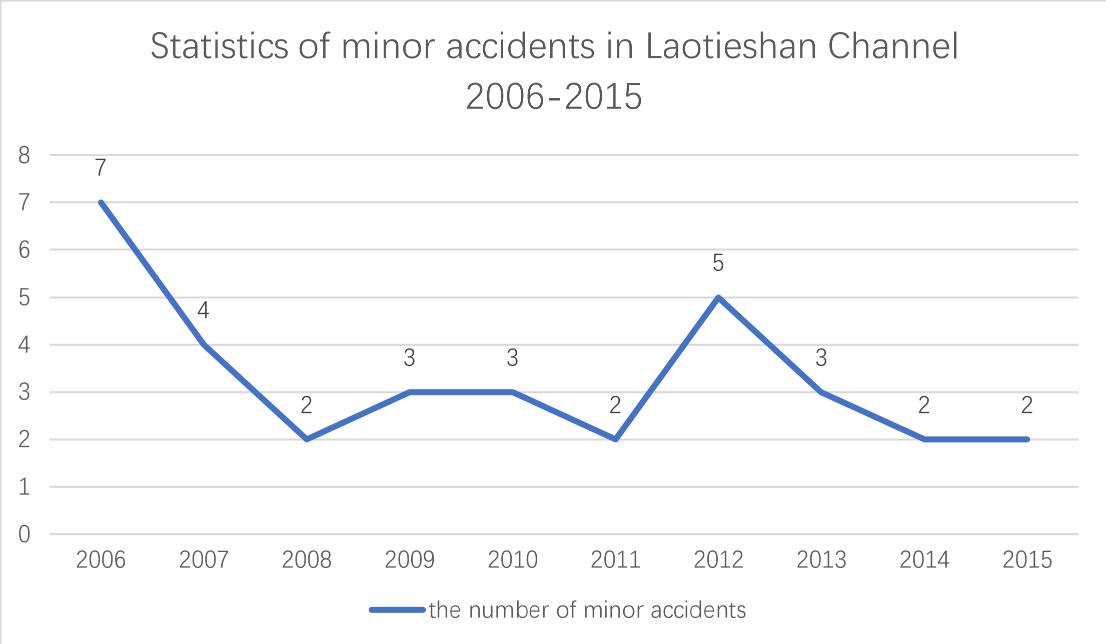


Figure 5.2 Statistics of Minor Accidents in Laotieshan Channel 2006-2015.

Data source: Dalian MSA. Statistics of maritime traffic accident in Dalian sea areas, 2016.

Figure 5.2 shows that the number of minor accidents dropped significantly from 2006 to 2008, it is because the shipping industry boomed in 2006, the number of ships soared. But there were many ships over the service time and with a variety of hiding risks still in operation continuously, moreover a large number of low-standard crews got into the shipping market as well as some new shipping companies lacked good management. Therefore, under the influence of these factors, there had been a peak of minor accidents occurring frequently. In this case, the relevant administration authorities had adopted some regulations involving in the crew, ship and shipping company management to develop the maritime safety. In addition, more strict sanctions are given to illegal companies and crews, and improvement of the quality of the crews based on some maritime colleges and more investment are provided for waterways, such as increasing the number of beacons, VTS stations and other infrastructures and so on. Finally, the number of minor accidents reduced obviously between 2007 and 2008 that was kept in stable about 2 to 3 per year from 2008 to 2011. The number increased to 5 only in 2012. This is because the maritime traffic accidents are characterized by randomness. After that, it still returned to 2 to 3 minor accidents happening per year in the period of 2013-2015.

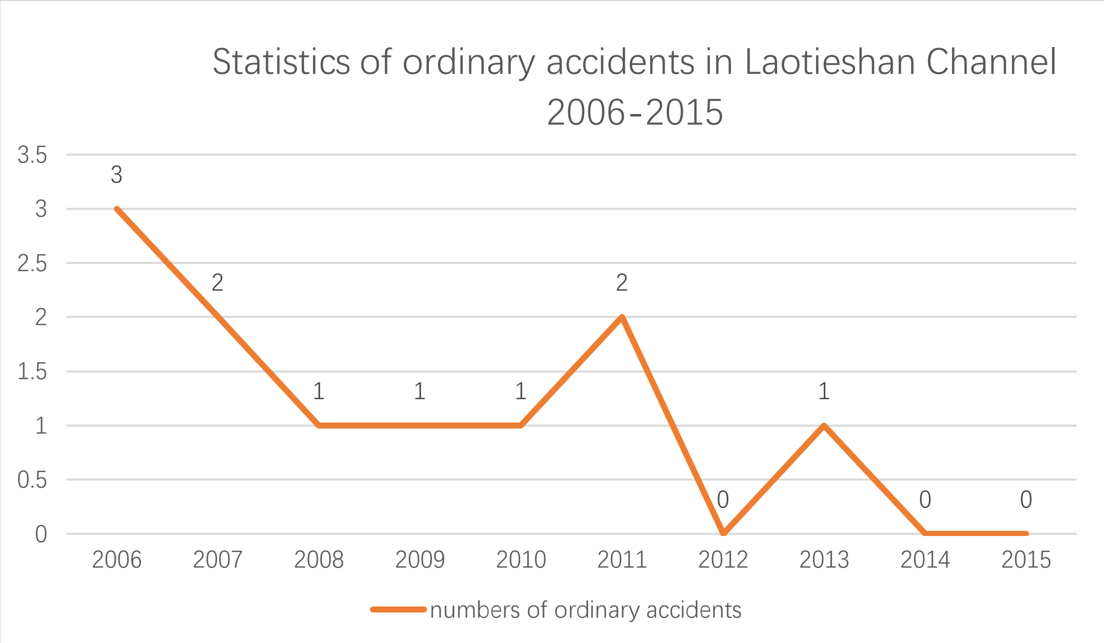


Figure 5.3 Statistics of Ordinary Accidents in Laotieshan Channel 2006-2015.

Data source: Dalian MSA. Statistics of maritime traffic accident in Dalian sea areas, 2016.

Through the analysis of Figure 5.3, the number of ordinary accidents occurring in Laotieshan Channel is relatively few from 2006 to 2015, and the trend of which is decreasing and approaching to zero gradually. The ordinary accident occurred 4 times in the year of 2006 because of the brisk shipping market. And then the number was reducing and kept in 1 accident per year from 2007 to 2010. In 2012, 2014 and 2015, there was no ordinary accident happening that provided a good environment for the maritime traffic safety in Laotieshan Channel.

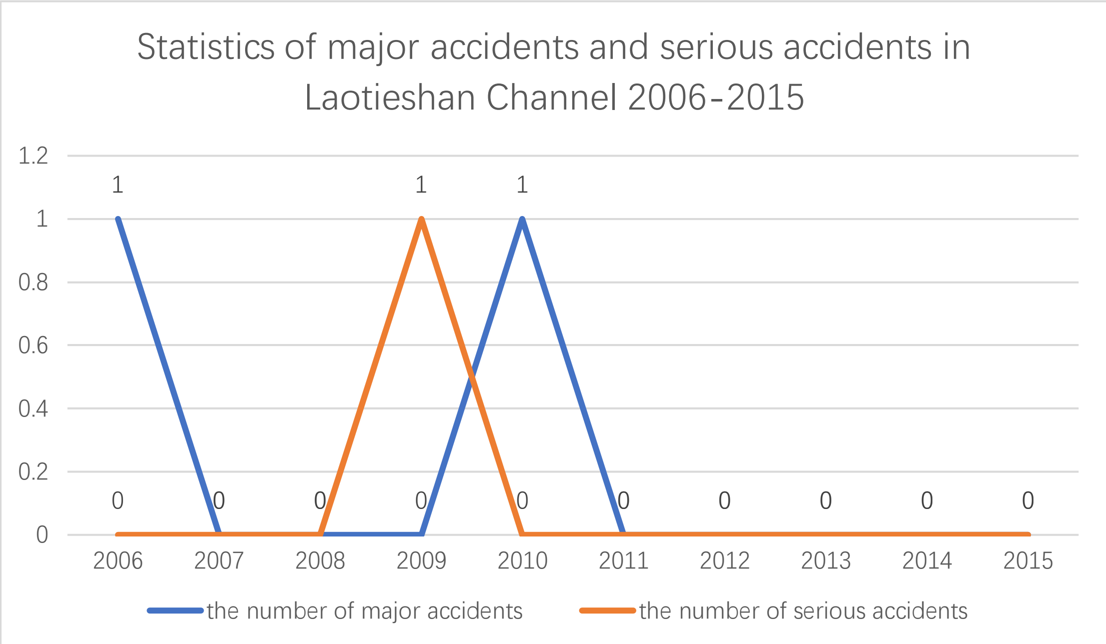


Figure 5.4 Statistics of Major and Serious Accidents in Laotieshan Channel 2006-2015. Data source: Dalian MSA. Statistics of maritime traffic accident in Dalian sea areas, 2016.

Figure 5.4 shows that the major accident and serious accident occurred rarely in Laotieshan Channel 2006-2015, but from the trend of line can be seen that there is still some fluctuations of them. By the analysis above, the year of 2006 was the period that maritime traffic accidents in various levels broke out and reached the maximum in Laotieshan Channel. This is due to the brisk shipping market, complex traffic conditions, substandard management and the low-quality crews. But after that, it can be seen the maritime traffic accidents had been in very good control. We should note the randomness and suddenness of the maritime traffic accident itself. As the result of huge economic losses and serious harms caused by major accident and serious accident, although both of the accidents occurred rarely in Laotieshan Channel, the maritime administration authorities should strengthen the maritime safety supervision constantly to prevent the accidents from rebounding recently.

5.1.2 In Various Time (Month)

The occurrence of maritime traffic accident has the obviously seasonal fluctuation, therefore, there is more practical significance for monthly statistics on the accidents. According to the time (month) statistics of the accident that happened, the total number of accidents, the number of minor accidents, ordinary accidents, major accidents and serious accidents in Laotieshan Channel during the period of 2006 to 2015 would be statistically analyzed. See Figure 5.5 for details.

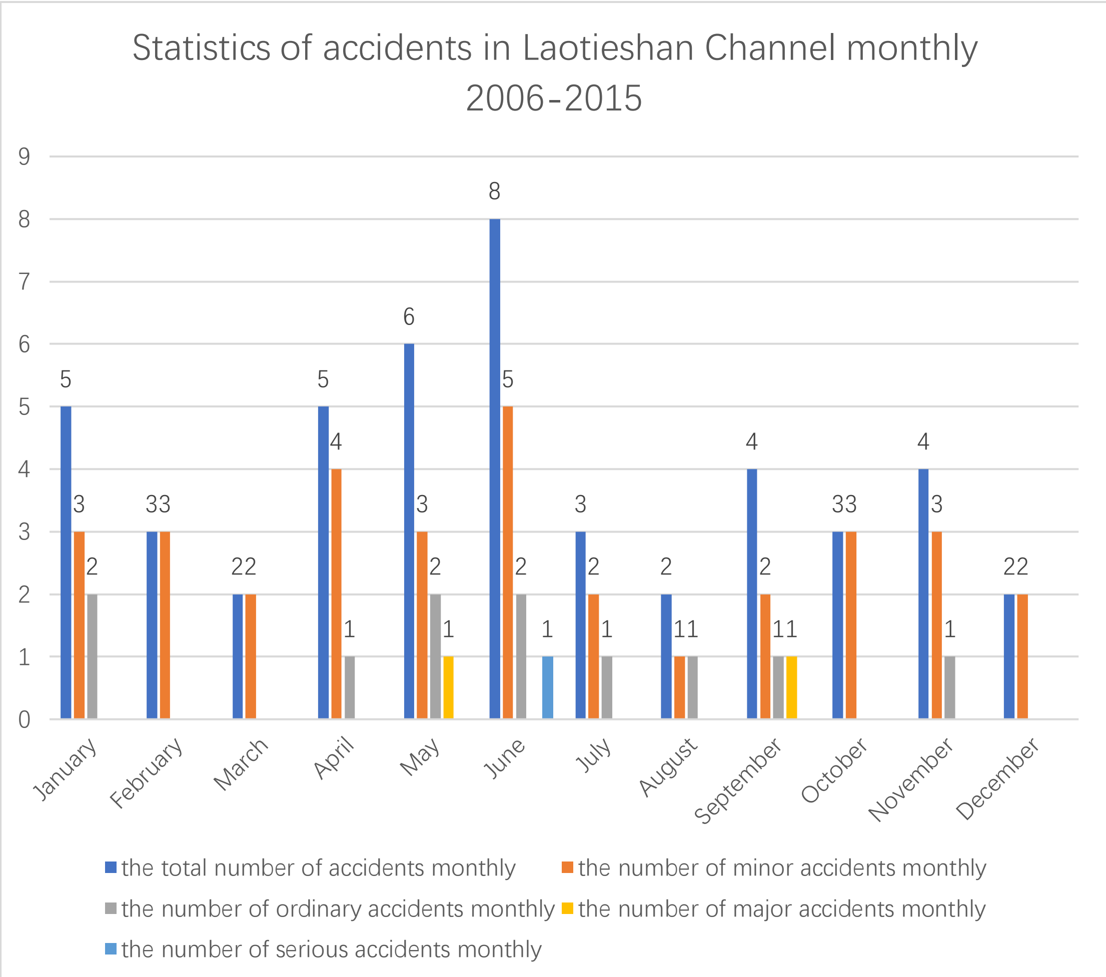


Figure 5.5 Statistics of Accidents in Laotieshan Channel Monthly 2006-2015.

Data source: Dalian MSA. Statistics of maritime traffic accident in Dalian sea areas, 2016.

Figure 5.5 shows that, on the whole, the second quarter of the year is a peak period of maritime traffic accidents occurring. Accidents happened more frequently in the May and June. This is mainly because in spring, the fog appears frequently in Laotieshan Channel, and maritime activities are increasing gradually, the fog and the human errors resulted in the increase of maritime traffic accidents. While in the first quarter of the year, the temperature in the sea area is low, some parts of which is freezing from the beginning of January to March, therefore, the rate of maritime traffic accident is relatively low due to climate factors in the first quarter of one year.

5.1.3 In Various Ship Type and Accident Category

Table 5.1 Accidents Statistics in Various Ship Type and Accident Category in Laotieshan Channel 2006-2015.

	Passenger ship	Oil tanker	Container ship	General cargo	Bulk carrier	Tug	Fishing boat	Other ship
Collision	1	2	3	7	2	1	4	1
Grounding	0	1	1	2	1	0	0	0
On rocks	0	1	0	1	1	0	0	0
Contacting damage	0	1	1	4	2	0	0	0
Wave damage	0	0	0	1	0	0	0	0
Fire and explosion	0	1	0	2	1	0	0	0
Wind Damage	0	0	0	0	1	0	0	0
Self-sinking	0	0	0	2	0	0	0	0
Other accidents	0	1	0	0	1	0	0	0
In total	1	7	5	19	9	1	4	1

Data source: Dalian MSA. Statistics of maritime traffic accident in Dalian sea areas, 2016.

From Table 5.1 we can see that the type of ships involved in the most accidents is the general cargo ship (19 accidents for general cargo ships in total, the proportion of which is close to 40%). The number of accidents involved in fishing boat collision, oil tanker on fire and bulk carrier on rocks accidents also accounted for a large proportion in the same category of accidents.

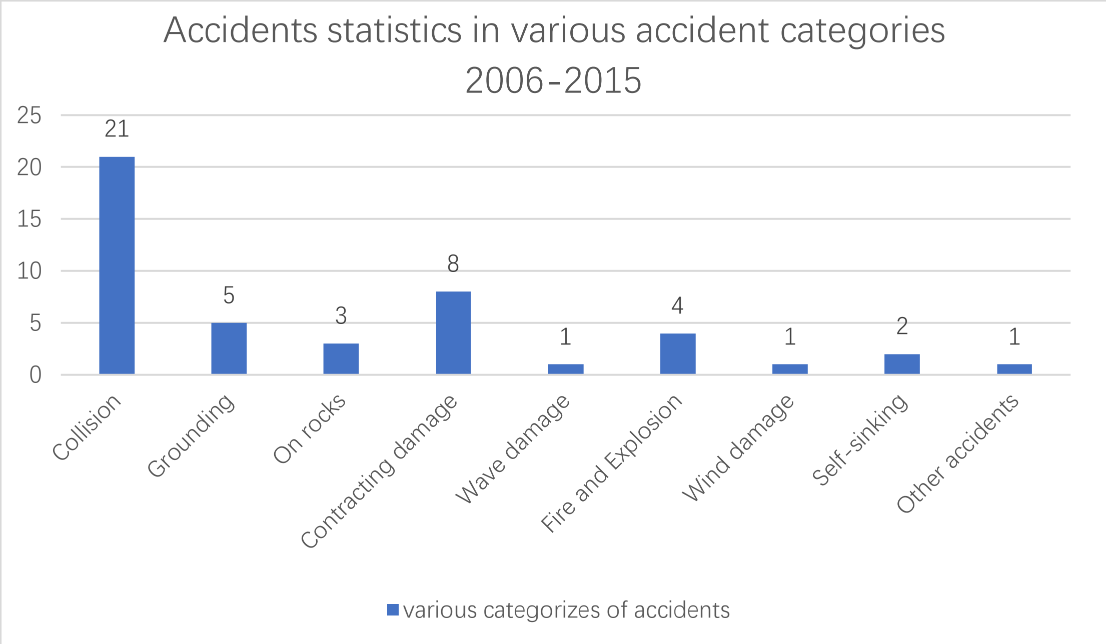


Figure 5.6 Accidents Statistics in Various Accident Categories 2006-2015.

Data source: Dalian MSA. Statistics of maritime traffic accident in Dalian sea areas, 2016.

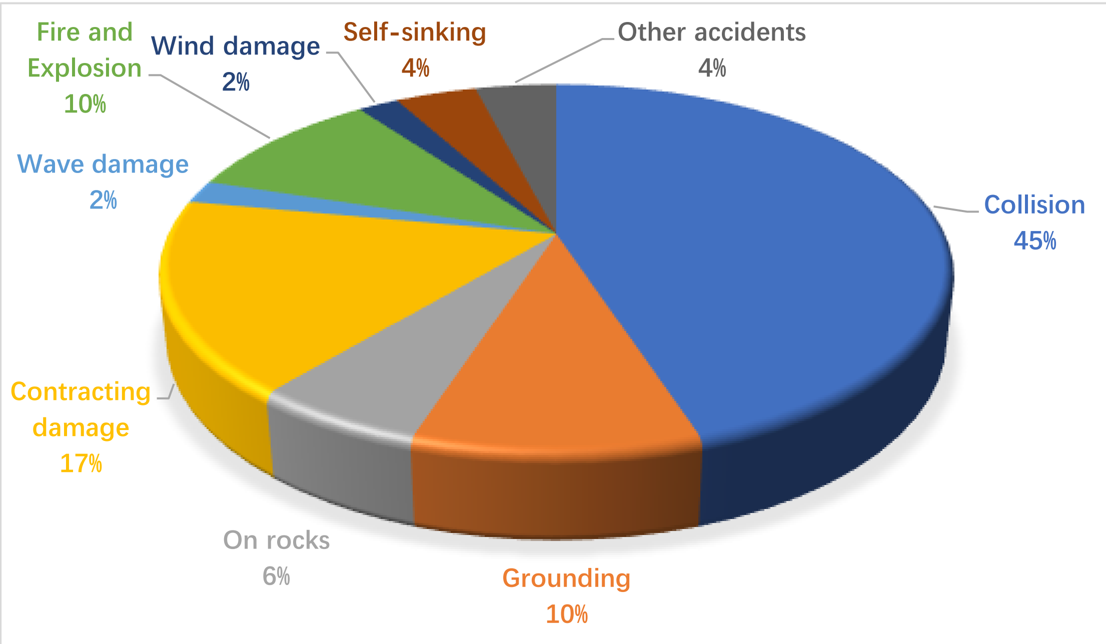


Figure 5.7 Proportion of Accidents in Various Categories 2006-2015.

Data source: Dalian MSA. Statistics of maritime traffic accident in Dalian sea areas, 2016.

From Figure 5.6 and 5.7, in all accidents, the number of collision accidents was 21 that accounted for 45%, 5 grounding accidents accounted for 10%, on rock accidents accounted for 1%, and the number of which was 3, 8 contacting damage accidents accounted for 21%, fire accidents accounted for 8%, wave damage and wind damage accounted for 2% respectively, the number of self-sinking accidents was 2 that accounted for 4% of all. The collision accident is the most common category of maritime traffic accidents occurred in Laotieshan Channel, so the accident causation analysis of maritime traffic accidents especially for collision accidents is significant for accident prevention and reduction. Laotieshan Channel is the “throat” of Bohai Sea that is the only way for large vessels entering and leaving Bohai sea. Although the ship routing scheme for vessels in Laotieshan Channel has been implemented, encountering situation still occuring frequently because of the intensive vessel traffic flows and complicated traffic conditions that allow the collision accidents occurred frequently.

5.2 Accident Causation Analysis in Laotieshan Channel

Based on the maritime risk prejudgment and accident characteristics analysis of Laotieshan channel done before, the fault tree analysis method would be used to identify the accident causation factors.

5.2.1 Fault Tree Analysis Method

The fault tree is a kind of directed logic diagrams, which is used to describe and analyze the accident from the reason to the result gradually (Liu, J.M., 2011). It is beginning with the consequence of the accident to analyze and identify corresponding causation factors. According to analysis and research gradually, it is used to identify the direct cause of the accident and discover the indirect cause and potential risk factors in deep, and the relations among the causation factors could be represented by which as a logic diagram.

In the practical application of fault tree analysis method, due to the different requirements and purposes of various objects, the specific method would be different, but generally speaking, the process of analysis could be divided into:

a. Identification of the system need to be analyzed;

b. Investigation and study of the specific accidents that have occurred in the system;

c. Identification of the top event in the system;

d. Investigation of all the factors related to the top event;

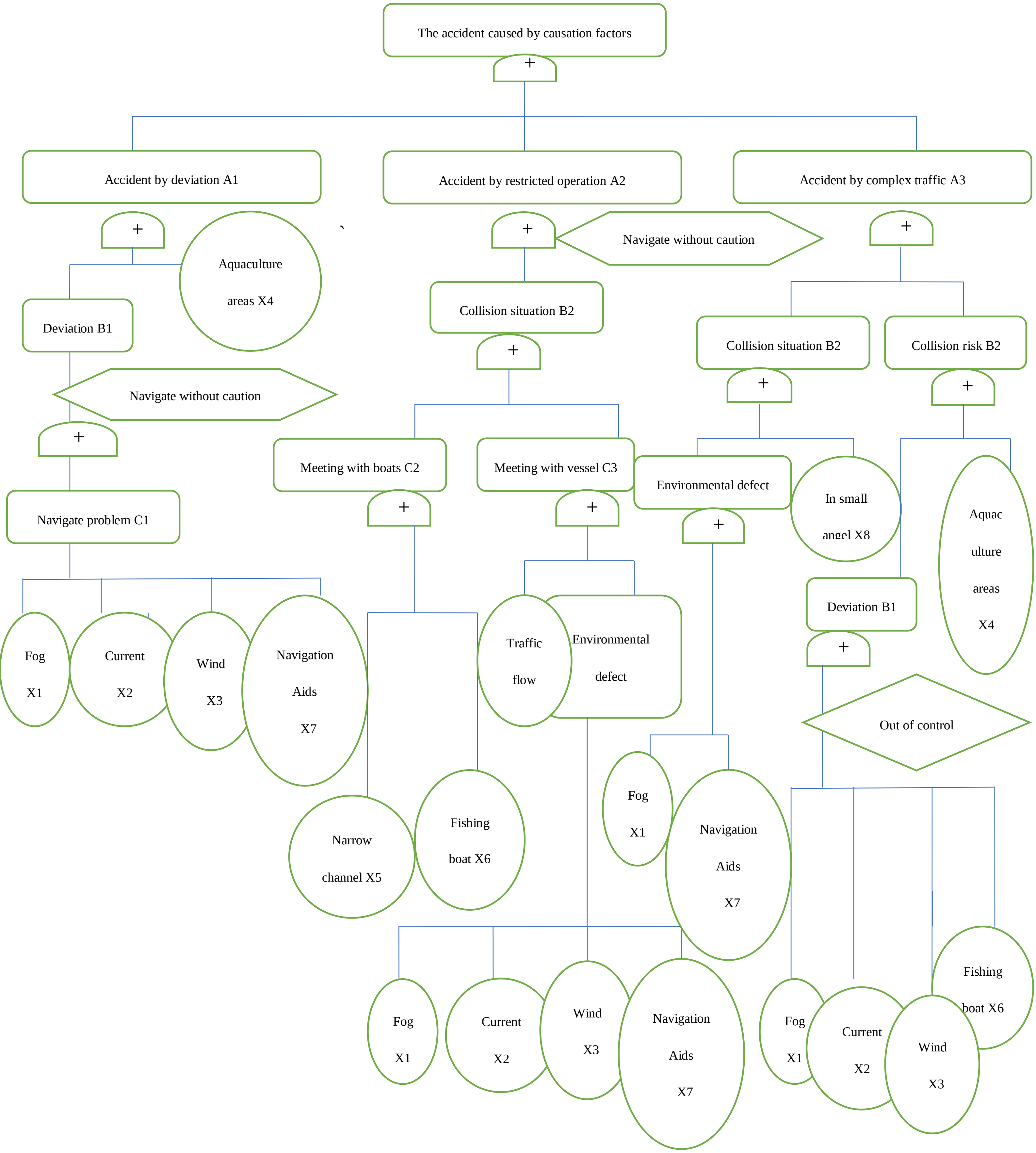
e. Drawing the fault tree;

f. Quantitative analysis based on the fault tree (Xu, X.X., 2008).

5.2.2 Fault Tree of Accident Causation Factors of Laotieshan Channel

According to the statistics of maritime traffic accident in Dalian sea areas 2006-2015, there are 47 accidents that happened in Laotieshan Channel, the direct causes of which could be categorized into deviation from the original route; complex traffic flow in ship routing system and restricted operation of the ship. There are nearly 80% of all the accidents caused by these three reasons directly, therefore, which could be regarded as the most direct reasons of the top event in the fault tree. And then a logic fault tree analysis model was established based on the detail analysis of the accidents. From the top event of the fault tree, the direct cause of each incident should be identified gradually until the basic event which is the accident causation factors affecting the maritime safety in Laotieshan Channel has been found.

The fault tree has been established as Figure 5.8 and the basic evens have been listed as (X1-X8): X1-fog, which represents the influence by the fog; X2-current, means the influence by the current of the sea area; X3-wind, the wind is strong; X4- aquaculture areas or obstructions, aquaculture areas and obstructions are widely distributed; X5-channel, the width of the channel is too narrow to pass through; X6-fishing boat, the number of fishing boats is large; X7- navigation aid facilities, there is no enough navigation aid facilities; X8-meeting angle, meeting in small angle of vessels.



The accident caused by causation factors
+
Accident by deviation A1
Accident by restricted operation A2
Accident by complex traffic A3
+
Aquaculture
areas X4
Deviation B1
Navigate without caution
+
Navigate problem C1
Fog
X1
Current
X2
Wind
X3
Navigation
Aids
X7
+
Navigate without caution
Collision situation B2
+
Meeting with boats C2
Meeting with vessel C3
+
+
Narrow
channel X5
Fishing
boat X6
Traffic
flow
Environmental
defect
Fog
X1
Current
X2
Wind
X3
Navigation
Aids
X7
+
Collision situation B2
Collision risk B2
+
+
Environmental defect
In small
angel X8
+
Fog
X1
Navigation
Aids
X7
Aquac
ulture
areas
X4
Deviation B1
+
Out of control
Fog
X1
Current
X2
Wind
X3
Fishing
boat X6

Figure 5.8 Fault Tree of Accident Causation Factors of Laotieshan Channel.

Source: Author.

In all the accidents, there are 11 accidents occurring which are associated with the fog (X1), thus it is recorded as X1 = 11; 9 accidents are associated with the current (X2), so X2 = 9; X3 (wind) = 7; X4 (aquaculture areas) = 15; X5 (narrow channel) = 10; X6 (fishing boat) = 13; X7 (navigation aid facilities) = 2; X8 (meeting in small angle) =8.

Table 5.2 Accident Causation Factor Analysis of Laotieshan Channel 2006-2015.

Accident causation factor	Description	Sign	Value
Fog	Influence of fog	X1	11
Current	Influence of current	X2	9
Wind	The wind is strong	X3	7
Aquaculture areas and obstructions	Wide distribution of Aquaculture areas and obstructions	X4	15
Narrow channel	The width of the channel is too narrow	X5	10
Fishing boat	The number of fishing boats is large	X6	13
Navigation aid Facilities	Navigation aid facilities are not enough	X7	2
Meeting angle	Meeting in small angle of vessels	X8	8

Source: Author.

The accident rates of various typical accidents caused by accident causation factors are mainly measured by the ratio of the number of the most direct basic events in various typical accidents caused by accident causation factors with total number of accidents happening in the area. It mainly indicates the extent of influence of a causation factor leading to the occurrence of the accident. According to the relevant statistical data of 47 maritime traffic accidents from 2006 to 2015 that occurred in Laotieshan Channel, the calculation results of the accident rate caused by the accident causation factors (X1-X8) can be obtained as follows:

$f_1 = \frac{X_3}{T} = \frac{11}{47} = 0.234;$

$f_2 = \frac{X_2}{T} = \frac{9}{47} = 0.191;$

$f_3 = \frac{X_3}{T} = \frac{7}{47} = 0.143;$

$f_4 = \frac{X_4}{T} = \frac{15}{47} = 0.319;$

$f_5 = \frac{X_5}{T} = \frac{10}{47} = 0.213;$

$f_6 = \frac{X_6}{T} = \frac{13}{47} = 0.277;$

$f_7 = \frac{X_7}{T} = \frac{2}{47} = 0.043;$

$f_8 = \frac{X_8}{T} = \frac{8}{47} = 0.17.$

Based on the result calculated above, the extent of influence of the accidents caused by various causation factors could be ranked as follows:

$f_4 > f_6 > f_1 > f_5 > f_2 > f_8 > f_3 > f_7$

Therefore, the conclusion could be confirmed that the most significant causation factor influencing the maritime safety in Laotieshan Channel is wide distribution of the aquaculture areas. The second most important factor is the large number of fishing boats in Laotieshan Channel. And the influence of the fog is the third most important factor. In addition, the ranking of other accident causation factors is that the width of the channel is narrow; the influence of the current; meeting situation of vessels in small angle; the influence of the wind. The least significant factor is that the navigation aid facilities are not enough.

5.3 Concluding Remarks

From 2006 to 2015, there were 47 maritime accidents occurring in Laotieshan Channel, which caused 37 people dead, 40 ships sinking and 112 million RMB of direct economic losses in total. Among these 47 maritime traffic accidents, there were 33 minor accidents, 11 ordinary accidents, 2 major accidents and 1 serious accidents.

The characteristics of accidents in Laotieshan Channel from 2006 to 2015 has been analyzed in various ranking, time, ship type and accident category. The conclusions have been obtained that most accidents are minor accident occurring in 2006 due to the flourishing shipping industry; the second quarter of a year is a peak period of maritime traffic accidents occurring, May and June especially; and the general cargo ship is the most common ship type involves in accidents.

In addition, the fault tree is a kind of directed logic diagrams, which is used to describe and analyze the accident from the reason to the result gradually, based on that the accident causation factors of Laotieshan Channel have been identified and ranked according to different severity of which. It is found that the most significant causation factor influencing the maritime safety in Laotieshan Channel is wide distribution of the aquaculture areas. And the ranking of the other factors in various severity of them is large number of fishing boats, the influence of the fog, the width of channel is narrow, the influence of current, meeting in small angle of vessels, the strong wind, and the least significant factor is the navigation aid facilities are not enough.

CHAPTER 6

Conclusions and Recommendations

6.1 Conclusions

As a "throat", Laotieshan Channel has undertaken the enormous pressure of transportation for vessels entering and leaving Bohai Bay day and night, especially the rapid development of the shipping industry in the china. Therefore, maritime traffic accident occurred frequently in the Channel in recent years. Although according to the adaptation of relative laws and regulations by maritime administration authorities, more strict sanctions were given to the crew and companies with violation, the accident still could not be reduced and eliminated effectively, especially for major accident and serious accident which always result in huge losses and serious damage. Thus, maritime risk prejudgment and accident causation identification have more practical significance of accident prevention and counter measures construction of Laotieshan Channel.

In this research paper, in addition to interpretation of accident research status in China and in the world, three typical accident analysis models have been introduced and compared in order to illustrate the analysis mechanism and process of accident analysis, besides, most of models used widely are conceptual, which are lack of relative quantitative analysis. Therefore, quantification data and relative calculation would be used for maritime risk prejudgment and accident causation identification according to certain mathematical methods in this paper.

Since 2006, the implementation of ship routing scheme in Laotieshan Channel, the vessel traffic flow in which has been divided into two directions – east and west by the separation area. However, the maritime traffic accident still occurred frequently for the complex maritime traffic conditions. Maritime traffic conditions influencing the maritime safety of Laotieshan Channel have been analyzed from the respects of natural condition, track distribution, ship speed, vessel traffic flow, ship type and ship route. It has been identified that strong wind, huge wave and fog affect the vessel traffic flow mainly from Yingkou, Qinhuangdao, Tianjin and other ports occasionally; the average speed of eastbound vessels is a little slower than westbound vessels; moreover, the bulk carrier and general cargo ship are the most common ship type used for transportation in the channel.

This chapter has analyzed and processed the data of vessel traffic flow and vessel traffic conflict of Laotieshan Channel based on water traffic conflict theory and relative mathematical probability statistics method. Laotieshan Channel has been divided into 4 navigable sea areas which is traffic separation area, inshore traffic zone, warning zone and other sea areas nearby for maritime risk prejudgment respectively. Taking the traffic conflict rate as the index and the impact of various severity conflicts on maritime safety has been considered. According the risk prejudgment model established additionally, the maritime risk prejudgment result of various navigable sea areas of Laotieshan Channel could be obtained:

a. Warning zone is generally safe;

b. Traffic separation area is unsafe;

c. Inshore traffic area is unsafe as well;

d. Other sea areas nearby could be regard as safe.

From 2006 to 2015, there were 47 maritime accidents occurred in Laotieshan Channel, among which, 33 minor accidents, 11 ordinary accidents, 2 major accidents and 1 serious accidents. The characteristics of accidents in Laotieshan Channel have been obtained that most accidents are minor accident; the year of 2006 was the peak period of accident occurring due to the flourishing shipping industry; the second quarter of a year is the time when accidents occur frequently, May and June especially; and the general cargo ship is the most common ship type involves in accidents.

In addition, based on the fault tree analysis method, the most significant causation factor influencing the maritime safety has been identified was the wide distribution of aquaculture areas, and the ranking of the other accident causation factors in various severity is large number of fishing boats, the influence of the fog, the width of channel is narrow, the influence of current, meeting in small angle of vessels, the strong wind, and the navigation aid facilities are not enough.

6.2 Recommendations

Due to complex traffic conditions in Laotieshan Channel, strong wind, huge wave and fog affects at times, some relative measures should be proposed by maritime administration authorities, such as the traffic control used for vessels in the poor visibility or strong wind, maritime safety information broadcasted in time, in addition, strict implementation of ship routing scheme in channel for further management of vessel traffic flow, special regulations adopted for reducing the ship speed into an appropriate and safe extent. Besides, focusing on the key ship type in the key period, making full use of traffic organization and service functions of VTS, the general cargo ship and bulk carrier as the most common ship type involved in the accident, therefore, improvement of FSC and PSC for which to ensure the defects could be identified and corrected in advance. The second quarter of a year is the period of accident occurring frequently owing to the large number of vessels engaged in transportation after the cold winter and spring with strong wind and fishing ban per year in Laotieshan Channel, thus, improvement of maritime traffic management at that time would have more practical significance.

For maritime risk prejudgment of Laotieshan Channel, the inshore traffic zone and traffic separation area have been regarded as the unsafe sea areas for vessels, the ship reporting scheme should be implemented for these two areas, establishment of contact between VTS center and vessel sailing in which in order to the activity of vessels could be addressed constantly. If the condition permits, the number of VTS duty officers would be increased for these areas, and the navigation aid facilities such as beacons and radars should be improved and maintained well. The vessel speed is another significant risk affecting the maritime safety in Laotieshan Channel, thus, speed limitation of vessels in the inshore traffic zone and traffic separation area are also useful of reduction of the occurrence of accidents.

According to the accident causation factors influencing the maritime safety in Laotieshan Channel, a large number of collision accidents occurring between merchant ships and fishing boats in Laotieshan Channel. It's usually because of ineligible fishing crew who don't have valid certificates or are not familiar with the rules of collision avoidance on the sea. Some of fishing boats always exceed the bow of merchant ships deliberately, change their course blindly, even seek for collision with merchant ships. In addition, some of fishing boats don't equip with AIS, and VHF channels between fishing boats and the merchant ships could not be matched effectively that result in the failure of collision avoidance coordination. Therefore, the cooperation between maritime administration authorities and fishing administration authorities should be established to be familiar with the characteristics and regularity of fishing boats in Laotieshan Channel, and the collision avoidance training for fishing crew should be carried out by maritime administration authorities, moreover, based on the joint inspection, the illegal acts of fishing crew would be examined and dealt with for maritime traffic safety.

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